Vol. XVII, Part III June, 1947

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority
of
The Indian Council of Agricultural Research

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 3 or 5s.

Published by the Manager of Publications, Delhi.
Printed by the Government of India Press, Calcutta, India,
1948.

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VOL. XVII, PART III

(June 1947)

The Editorial Committee of the Indian Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

ORIGINAL ARTICLES

CITRUS ROOTSTOCK TRIALS IN THE PUNJAB

III. THE INFLUENCE OF DIFFERENT ROOTSTOCKS ON THE VIGOUR AND CROPPING OF MARSH SEEDLESS GRAPEFRUIT

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(Received for publication on 20 March 1947)

(With four text-figures)

CAPTAIN R. Mitchell [1946] of the Indian Mildura Fruit Farm, Montgomery, was probably the first to plant in 1925 a few trees of grapefruit in his orchard in the Punjab. A few years later, the Fruit Specialist, Punjab (Sirdar Bahadur Lal Singh), made several successful attempts in importing nursery trees of important varieties of this species from the U.S.A. for trials in the Punjab. As a result of these importations and trials, the Marsh Seedless variety gained sufficient prominence and popularity with citrus growers in the early thirties and the demand for budded trees of this variety increased tremendously by 1938.

Wherever grapefruit trees of this variety were planted in the Punjab, the quality of fruit produced was superb. The cropping was both regular and heavy and the trees were found to withstand adverse soil conditions better than even the Malta orange trees. These were some of the potent factors that prompted inclusion of this species in the rootstock trials reported by Lal Singh and Sham Singh [1942].

In western countries, particularly the U.S.A., the grapefruit is consumed as a breakfast fruit without an equal. It is an excellent appetizer and a stomachic. Its use is also finding favour with the people in India where, of late, it has been prescribed by physicians against malaria and as a blood purifier. The fruit ripens in the Punjab in the beginning of December and can be held on the trees till the end of March or even later if need be. It would, however, be better if the pickings are over by the middle of March so that the risk of shedding of flowers and fruit of the next crop is obviated.

It would be recalled that the results reported in the previous two articles in this series by Lal Singh and Sham Singh [1942 and 1944] pertained to the period when the trees were purely in their vegetative phase and, as such, the rootstock influence in case of various scion-stock combinations was reported in respect of 'tree vigour' only. Since then, data in respect of both 'tree vigour' and 'cropping' in case of all the four scions for a further period of four years have been collected and compiled. The present communication deals with such data in case of the Marsh Seedless grapefruit scion only. Similar information regarding the remaining three scions will be reported in due course as, due to various reasons, it was found impracticable to include it in this article.

With the commencement of fruit bearing, the rootstock influence is manifest in two different directions, *viz.*, increase in tree size on the one hand and fruit yield on the other. According to the programme laid down, data on both of these aspects has been and will continue to be collected year by year to study the relationship between these two aspects in case of different scion-stock combinations under trial. The underlying aim is to determine the suitability of a particular rootstock for a particular scion such that the increased production of fruit is consistent with tree vigour and longevity of trees in each case. The data reported here cover the period of first four years of fruit bearing in case of the Marsh Seedless grapefruit trees from 1940-41 to 1943-44.

MATERIAL AND LAYOUT

For details regarding the preparation of material and layout the reader is referred to a previous communication in this series by Lal Singh and Sham Singh [1942]. The various scion-stock combinations here under study are given in Table I.

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TABLE I

Different scion-stock combinations under trial

Field No.	Method of raising the rootstock	Name of scion-stock combination	No. of trees under study	English equivalents of root-stocks	Specific-names
4	Seed	Marsh Seedless on "Kharna Khatta"	24	*nil*	*C. Karna* Raf.
,,	,,	Marsh Seedless on "Jatti Khatti"	24	Rough lemon	*C. limonia* Osbeck
,,	,,	Marsh Seedless on "Mitha"	24	Sweet lime	*C. aurantifolia* Var. Swingle
,,	,,	Marsh Seedless on "Mokari"	24	Citron	*C. medica* Linn.
,,	,,	Marsh Seedless on "Chakotra"	24	Shaddock	*C. Maxima* Merril
9	Cutting	Marsh Seedless on "Kharna Khatta"	18	....	....
,,	,,	Marsh Seedless on "Jatti Khatti"	18	....	....
,,	,,	Marsh Seedless on "Mitha"	18	....	....
,,	,,	Marsh Seedless on "Mokari"	18	....	....

It is clear from the foregoing that the experimental material constituted two sets. In the one case the Marsh Seedless scion was budded on rootstocks raised from seed and, in the other, the same scion was budded on rootstocks propagated by the rooting of stem cuttings. The two groups of experimental material, thus prepared, where planted separately into two fields and treated as two independent and self-contained experiments. The results of both the trials are embodied in the present communication with a view to study the performance of the Marsh Seedless grapefruit trees growing on rootstocks propagated both from seeds and cuttings.

Data collected

The girth measurements of all the trees under investigation were taken at a fixed point above the union year by year [Lal Singh and Sham Singh, 1942]. The yield of trees was recorded by counting the number of fruits on each tree when they were still green and unripe so as to avoid the vitiation of results through such possibilities as pilferage and damage by birds, etc. The number of fruits was again counted at the time of picking and compared with yields recorded previously. This double check was found to be very helpful in having a correct idea of fruit yield in each case.

DISCUSSION OF RESULTS

The year to year data in respect of vigour (indicated by stem-girth measurements) and cropping (indicated by number of fruits borne per tree) of the Marsh Seedless trees as influenced by different rootstock in both the field trials are compiled separately in Tables II and III.

TABLE II

Tree size and cropping of the Marsh Seedless trees growing on certain rootstocks propagated from seeds*

Year of observation	Growing season	Rootstocks													
		Kharna Khatta		Rough lemon		Shaddock		Sweet lime		Citron		S.E.		C.D.	
		girth	yield	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield
1940	1939	18·7	..	18·3	..	16·6	..	14·7	..	12·4	..	0·48	..	1·50	..
1941	1940	27·7	25	27·2	9	25·1	11	19·7	22	15·4	14	0·52	..	1·50	..
1942	1941	35.2	58	35·3	42	32·6	46	23·6	36	18·8	14	0·78	5·42	2·3	11
1943	1942	41·0	219	41·8	141	38·6	119	26·0	43	20·9	20	0·86	15·6	2·8	46
1944	1943	44·4	363	46·5	263	42·6	239	27·9	78	22·5	49	1·12	14·8	3·3	44

* Planted in January, 1937

TABLE III

Tree size and cropping of the Marsh Seedless trees growing on certain rootstocks propagated from cuttings*

Year of observation	Growing season	Rootstocks											
		Kharna Khatta		Rough lemon		Sweet lime		Citron		S.E.		C.D.	
		girth	yield	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield
1940	1939	21·2	..	20·3	..	15·8	..	15·5	..	0·375	..	1·2	..
1941	1940	29·5	44	30·1	27	20·4	32	18·8	28	0·542	3·8	1·6	11
1942	1941	36·6	65	39·1	48	24·8	39	23·1	26	0·549	3·02	1·7	9
1943	1942	41·7	265	46·3	201	27·5	94	25·8	74	0·635	15·76	1·9	47
1944	1943	46·2	296	52·1	271	30·9	88	28·5	63	0·883	8·62	2·7	26

* Planted in January 1937

Comparison of data in Tables II and III

The data in tables II and III show that no crop was taken from the trees for the first four years (1937-1940). This gave the trees in both the field experiments sufficient time to build up mechanically strong framework. The first crop, picked in 1941, was a light one in each case but more so in case of trees growing on rootstocks propagated from seed. This point is significant in so far as it reveals the precocious nature of trees on rootstocks raised from cuttings which also developed better size during the period of vegetative phase than those on rootstocks raised from seed. To form an idea of comparative tree size and cropping of trees on both sets of rootstocks, the data in Tables II and III are amalgamated in Table IV.

TABLE IV

The comparative tree size and cropping of the Marsh Seedless trees growing on certain rootstocks raised both from seeds and cuttings

Rootstock under trial	Method of raising the rootstock	1941		1942		1943		1944	
		girth in cm.	yield	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield
Kharna Khatta	Seeds	27·7	25	35·2	58	41·0	219	44·4	363
do.	Cuttings	29·5	44	36·6	65	41·7	265	46·2	296
Rough lemon	Seeds	27·2	9	35·3	42	41·8	141	46·5	263
do.	Cuttings	30·1	27	39·1	48	46·3	201	52·1	271
Sweet lime	Seeds	19·7	22	23·6	36	26·0	43	27·9	78
do.	Cuttings	20·4	32	24·8	39	27·5	94	30·9	88
Citron	Seeds	15·4	14	18·8	14	20·9	29	22·5	49
do.	Cuttings	18·8	28	23·1	26	25·8	74	28·5	63

The data for girth and yield for all the four years show that the initial advantage in tree size and cropping in favour of trees on rootstocks raised from cuttings persists for the entire period and holds good for all the rootstocks under trial except in one solitary case in 1944 when trees on Kharna Khatta rootstocks raised from seed gave a higher yield. In other words, so far as tree size is concerned, the Marsh Seedless trees on rootstocks raised from seeds have not been able to catch up with the corresponding trees on rootstocks raised from cuttings. The same generally holds good in respect of cropping as well, except in one solitary instance out of sixteen comparisons when trees on " seedling rootstocks " outyielded those on " cutting rootstocks ". These results show that size difference caused in the pre-orchard months may continue to persist much longer than is commonly known and believed. The same appears to hold good in respect of cropping as well. These points in favour

of rootstocks raised from cuttings appear to have a special significance so far as the performance of trees in early years at least is concerned. It would, however, be interesting to know whether and, if so, how long the trees on root stocks raised from cuttings would continue to remain in advantageous position both with regard to tree size and cropping. To throw further light on this aspect, the data in Tables II and III are plotted and are shown in Figs. 1 to 4. In Figs. 1 and 2, the size of trees from year to year, as indicated by trunk girth, is plotted and in Figs. 3 and 4, the yearly cropping in case of these very trees has been shown.

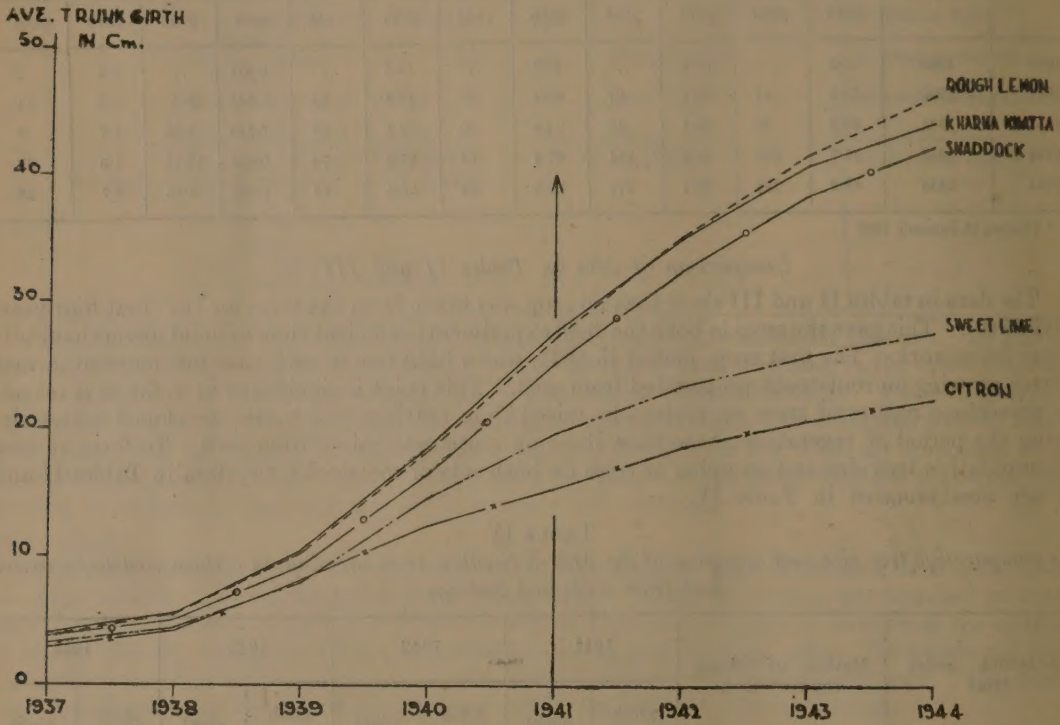

Fig. 1. Tree size on "Seedling Rootstocks"

The tree size. In Fig. 1 are plotted the data for tree size in respect of rootstocks raised from seed while in Fig. 2, similar data for rootstocks raised from cuttings have been shown. The rootstocks under study in both the experiments are identical except that in fig. 1 an additional rootstock, namely shaddock, is also included.

The data for tree size from 1937 to 1940, shown also in Figs. 1 and 2, have been fully discussed in a previous communication in this series by Lal Singh and Sham Singh [1942]. Briefly it may be stated that by the year 1940, considerable divergence or spread has been shown by the curves for rootstocks raised from seed (Fig. 1) so much so that the trees on five different rootstocks under study were classed by these authors in four different categories with respect to tree size. The divergence in growth curves in case of trees on rootstocks raised from cuttings (Fig. 2) is also well marked by 1940, and the four rootstocks here under study were found by Lal Singh and Sham Singh [1942] to fall in two groups only " Kharna Khatta " and rough lemon being in one group and sweet lime and citron being in the other.

The year 1941 was the first year of crop harvest in both the field experiments as shown by the arrow lines in Fig. 1 and 2. The curves in both the figures show a flattening tendency after 1941 indicating a fall in growth rate due to fruit production but the trees on rough lemon have been less affected than others. In view of this comparatively less decreased rate of growth in case of trees on rough lemon in both the field experiments, the tree size on this rootstock has comparatively improved

as compared to " Kharna Khatta ", which was leading all rootstocks in this respect till 1941 in case of " Seedling Rootstocks " (Fig. 1) and till 1940 in case of " Cutting Rootstocks " (Fig. 2). By

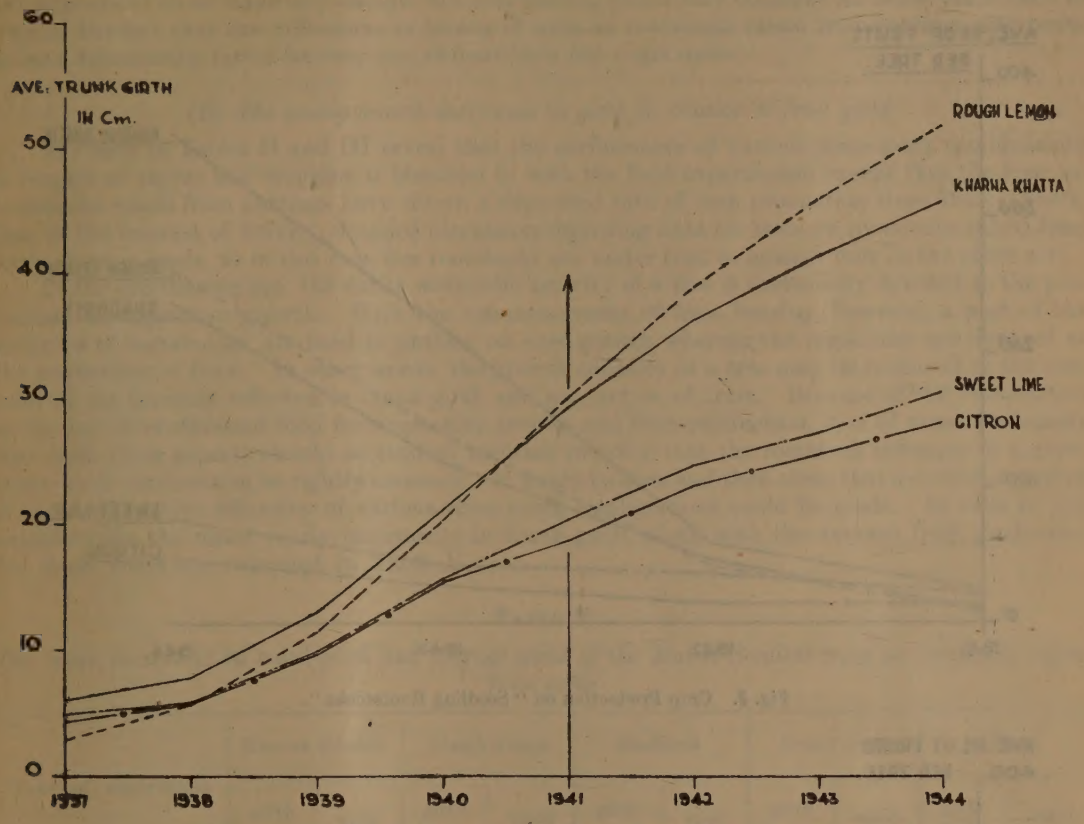

Fig. 2. Tree size on " Cutting Rootstock."

the end of 1944, the performance for tree size in case of rootstocks raised from seed (Figure 1) has not significantly changed from that reported earlier by Lal Singh and Sham Singh [1942], but that the trees on rough lemon rootstocks have all along been improving in size as compared to those on " Kharna Khatta ". The performance for tree size in respect of rootstocks raised from cuttings has (Fig. 2), however, considerably changed since 1940. By 1941, the two dwarfing rootstocks have fallen in two distinct groups and this position has remained unaltered since then. The other two rootstocks associated with vigour of scion trees reversed position in 1941 and by 1942 the trees on rough lemon have been significantly more vigorous than those on " Kharna Khatta ". This order of vigour has since been maintained by these two rootstocks.

The crop production

As has been previously stated, the fruit was harvested for the first time in 1941 in case of both the field experiments. The data for crop production in respect of rootstocks raised from seed are plotted in Fig. 3 while in Fig. 4, similar data for rootstocks raised from cuttings have been shown.

The crops had been rather sparse for the first two years of bearing—this being so in both the field experiments. But, as previously mentioned, the cropping was comparatively more in case of trees on rootstocks raised from cuttings. By 1943, the production increased considerably in both the experiments as is shown by a sharp rise of curves in both Figs. 3 and 4. This rate of production in case of rootstocks raised from seed (Fig. 3) has not only been maintained during 1944 but as the curves show there has also been a tendency for the trees on all the rootstocks to produce at a still

higher rate. On the other hand, in case of rootstocks raised from cuttings (Fig. 4), the rate of production in 1943 has not been maintained in 1944 by any of the four rootstocks under trial. In fact,

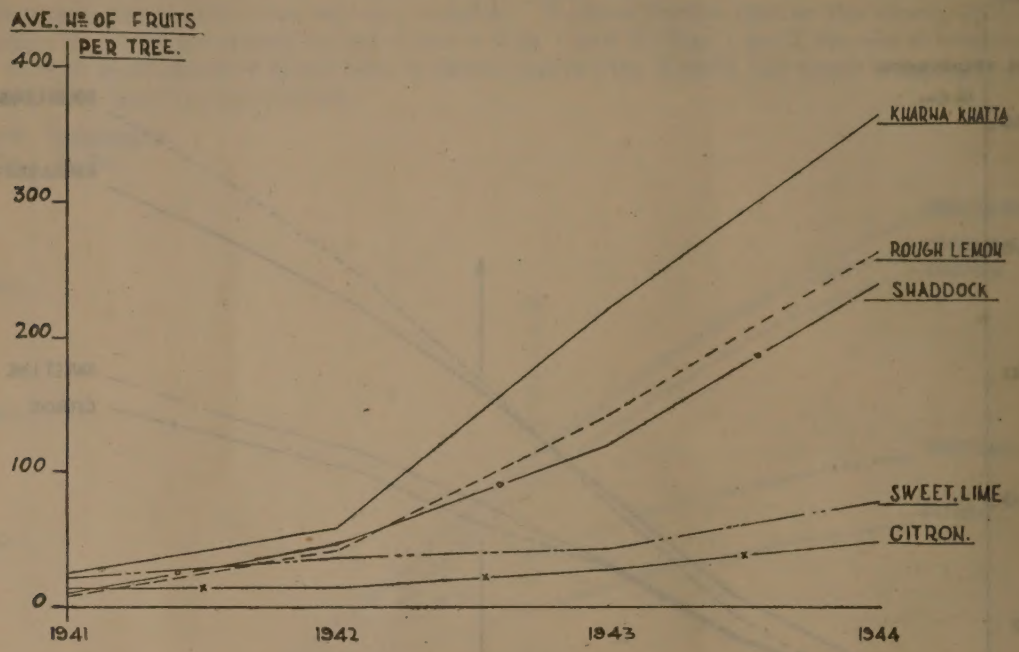

Fig. 3. Crop Production on "Seedling Rootstocks".

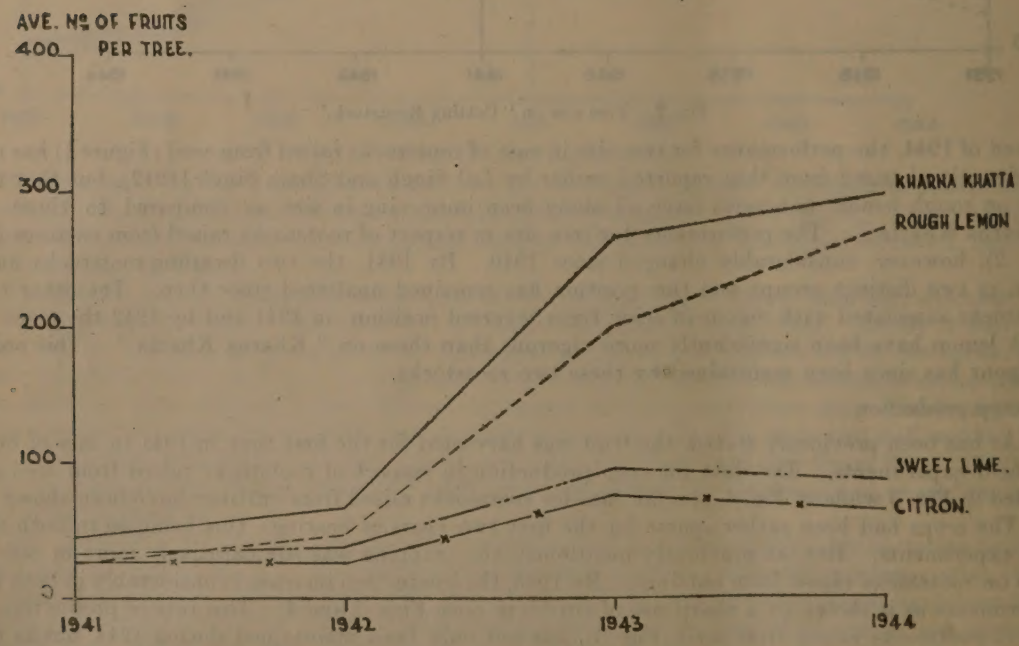

Fig. 4. Crop Production on "Cutting Rootstocks".

the productions in 1944 in case of sweet lime and citron had been actually less than those during the previous year. Therefore, the increased production in case of rootstocks raised from cuttings (Table IV) appears to be of transitory nature, but this passing phase may continue for some years more in view of the fact that size differences in favour of trees on rootstocks raised from cuttings may prove to be a determining factor for crop size at least for a few years more.

(B) The yearly growth increment in girth in relation to fruit yield

The data in Tables II and III reveal that the performance of various scion-stock combinations in respect of vigour and cropping is identical in both the field experiments except that the trees on rootstocks raised from cuttings have shown a depressed rate of crop production since 1943. Therefore, in the interest of brevity, detailed discussion regarding data for trees on rootstocks raised from seeds alone is made, as in this case five rootstocks are under trial as against four in the other set.

In the pre-bearing age, the entire metabolic activity of a tree is exclusively devoted to the production of vegetative growth. With the commencement of fruit bearing, however, a part of the products of metabolism are used in putting on new growth whereas the remainder are devoted to the production of fruit. In other words, the growth capacity of a tree may be reckoned as the sum total of the increase reflected in trunk-girth and production of fruit. Because of the competition in the use of synthesized food for vegetative growth and fruit production, it is of utmost necessity that both these aspects should be studied together in order that the rootstock influence in a given scion-stock combination be rightly assessed. It would be then and then alone that a correct appraisal of the comparative efficiency of various scion-stock combinations could be made. In view of this consideration the mean yearly increments in trunk-girth, along with the average fruit production for those years are compiled in Table V.

TABLE V

The mean increment in trunk-girth and average yield of the Marsh Seedless trees on rootstocks raised from seeds

Year of observation	Kharna Khatta		Rough lemon		Shaddock		Sweet lime		Citron	
	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield	girth in cm.	yield
1940	8·34	..	8·12	..	7·33	..	6·64	..	3·9	..
1941	9·0	25	8·9	9	8·5	11	5·0	22	3·0	14
1942	7·5	58	8·1	42	7·5	46	3·9	36	3·4	14
1943	5·8	219	6·5	141	6·0	119	2·4	43	2·1	29
1944	3·4	363	4·7	263	4·0	239	1·9	78	1·6	49

For the four-year period from 1937, when the trees were planted in the orchard, to 1940, *viz.*, so long as these trees remained in purely vegetable phase, there was a regular increase in the amount of growth put on by the trees year by year except for 1938. This, being the year immediately following the transplanting of trees in the orchard, was associated with considerable set back in growth in case of all the rootstocks [Lal Singh and Sham Singh 1942]. Even in 1941—the first year of fruit bearing—there had been a tendency in case of rootstocks associated with vigorous growing trees (" Kharna Khatta ", Rough lemon and Shaddock) to register slightly increased rate of growth as compared with dwarfing rootstocks (Sweet lime and Citron). This slight increase in the rate of growth over the previous year in case of rootstocks associated with vigorous growing trees probably accounts for their tendency to commence bearing later than those in the dwarfing group. From 1942 onwards, fruit production is much on the increase year by year for each scion-stock combination except in case of citron during 1942 whereas there had been a corresponding set back in growth in each case except in case of citron during the same year (1942). These observations lead us to the

irresistible conclusion that increase in fruit production is invariably accompanied by decrease in amount of growth made. Such an antoganism in growth and fruitfulness has been previously recorded in case of mango by Lal Singh and Khan, A.A. [1939]. Hatton [1935] reached a similar conclusion when he said that the fall in the increment of cross-section year by year is accentuated with increased cropping. To illustrate this relationship more vividly in the present case, the mean yearly increase in girth and yield in all cases have been expressed in percentages, keeping growth and yield of trees on " Kharna Khatta " for 1941 as the basis. The percentage figures so calculated are compiled in Table VI.

TABLE VI

The relative performance of the Marsh Seedless trees on rootstocks raised from seed

Year of observation	Kharna Khatta		Rough lemon		Shaddock		Sweet lime		Citron	
	girth	yield	girth	yield	girth	yield	girth	yield	girth	yield
1941	100	100	99	36	94	44	56	88	33	64
1942	83	232	90	168	83	184	43	144	38	56
1943	64	876	72	564	67	476	27	172	23	116
1944	38	1452	52	1052	44	956	21	312	18	196

The data in Table VI show that with " Kharna Khatta " as the rootstocks, the yearly growth increment of the Marsh Seedless trees has gone down by 62 per cent in four years as compared to the increase in fruit yield by 1452 per cent. In case of Rough lemon rootstock, the mean growth increment fell down by 47 per cent only and the production increased by 1052 per cent ; in case of Shaddock the amount of growth fell down by 50 per cent with a corresponding increase in production by 956 per cent ; in case of Sweet lime the annual mean growth decreased by 35 per cent with an increase in cropping by 312 per cent and in case of Citron the fall in growth increment amounted to 15 per cent only with a corresponding increase in fruitfulness to the extent of 196 per cent. It may perhaps be appropriate to further reduce these figures on a common level to facilitate comparison with a view to study the efficiency of various rootstocks under trial. Thus for every 1 per cent decrease in growth increment of grapefruit trees on " Kharna Khatta ", Rough lemon, Shaddock, Sweet lime and Citron, the corresponding increase in fruit production is 23 per cent, 22 per cent, 19 per cent, 9 per cent and 13 per cent respectively. This again shows the superiority of rootstocks associated with vigorous growing trees over those in the dwarfing group. The efficiency of various rootstocks under trial in respect of growth and cropping, therefore, may be put in the descending order as : " Kharna Khatta ", Rough lemon, Shaddock, Citron and Sweet lime. Yet, the last mentioned rootstock has been and still continues to be the popular rootstock with some nursery-men and quite a lot of prospective growers, for reasons previously mentioned by Lal Singh and Sham Singh [1942], ask for nursery trees budded on Sweet lime.

(C) The Statistical treatment of data given in Table V

(i) *Correlation between growth increment and cropping*

To study the relationship between increment in girth and the number of fruits borne in case of different scion-stock combinations in any one season, the values of correlation coefficients were worked out after eliminating differences due to blocks.

The figures thus obtained are set out in Table VII.

TABLE VII

Correlation coefficient between growth increment and fruit production in a particular year pertaining to various rootstocks under trial

Name of rootstock	No. of pairs examined	Degrees of freedom	Correlation coefficient	Expected value of correlation coefficient for P=.05
"Kharna Khatta"	24	14	—0·04	0·497
Rough lemon			—0·188	
Shaddock			—0·308	
Sweet lime			+0·254	
Citron			+0·137	

The above figures display a complete lack of correlation between the growth made and fruit produced in a particular year. In other words, irrespective of the rootstocks under trial, the growth and cropping appear to be quite independent of each other. On the contrary, the data in Table V clearly show that in case of all the scion-stock combinations under trial, the increase in cropping is associated with a corresponding decrease in amount of growth made. Therefore, the values of correlation coefficient between both the aspects of production were worked out as obtaining between the entire period of four years and in case of all the scion-stock combinations with results as given in Table VIII.

TABLE VIII

Correlation coefficient between growth increment and fruit yield in case of the Marsh Seedless trees for the four-year period from 1940-41 to 1943-44.

Rootstock	No of pairs examined	Degrees of freedom	Correlation coefficient	Expected value of correlation coefficient for P = .05
"Kharna Khatta"	24	17	—0·965	0·456
Rough lemon			—0·952	
Shaddock			—0·961	
Sweet lime			—0·770	
Citron			—0·510	

The negative correlations establish the view that increase in fruit production is accompanied by decrease in growth rate. This holds good for all the rootstocks under trial. The correlations are very high and almost perfect in case of "Kharna Khatta", Rough lemon and Shaddock. In case of the remaining two rootstocks, *viz.*, Sweet lime and Citron the correlations between growth increment and yield are not very high but are significant just the same.

It may be recalled (Table II) that the Marsh Seedless trees on "Kharna Khatta" are no longer associated with greatest vigour as was the case when they were in the vegetative phase, but in respect of cropping they are definitely far superior to those on the remaining rootstocks. Thus trees on Rough lemon now lead the rest in respect of tree size. Since with the commencement of bearing, the growth increment has fallen in case of each rootstock treatment, the question arises as to how an unit decrease in growth would be ultimately reflected in increased cropping. This point is best brought out by calculating the regression co-efficients for various scion-stock combinations under trial. The figures obtained are set out in Table IX.

TABLE IX

Regression coefficient in growth increment and yield of the Marsh Seedless trees for the period 1940-41 to 1943-44

Rootstock	Regression coefficient
"Kharna Khatta"	—66
Rough lemon	—59
Shaddock	—49
Sweet lime	—14
Citron	—11

The figures in Table IX show that the performance of the Marsh Seedless trees on "Kharna Khatta" rootstock remained outstanding for the first four years of fruit production. The trees on this rootstock are associated with maximum production for an unit decrease in growth rate. The next in order of merit are the trees on Rough lemon rootstock followed by those on Shaddock. The trees on Sweet lime and Citron have not only hopelessly fallen behind in tree size (Table II) but the crops produced in both cases have also been poor and uneconomic. Obviously this state of affairs has not merely been due to the smaller size of grapefruit trees on these two rootstocks but, as the regression coefficient values show, the trees on both these rootstocks are characterised by a low productive potential set up within them. In view of these considerations the unsuitability of sweet lime and citron as rootstocks for the Marsh Seedless grapefruit scion has been established within a short period of eight years after planting.

SUMMARY

1. The influence of certain rootstocks, propagated both from seeds and cuttings, on tree vigour and cropping of the Marsh Seedless grapefruit trees has been studied for a period of four years.

2. So far as tree size is concerned, the Marsh Seedless trees on rootstocks raised from seed have not been able to catch up with the corresponding trees on rootstocks raised from cuttings. The same generally holds good in respect of cropping as well except in one solitary instance out of sixteen comparisons when trees on "seedling rootstocks" outyielded those on "cutting rootstocks". The increased production in case of trees on "cutting rootstocks", however, appears to be of a transitary nature in view of their decreased rate of fruit production since 1943.

3. It has been shown that for every 1 per cent decrease in growth increment of grapefruit trees on "Kharna Khatta", Rough lemon, Shaddock, Sweet lime and Citron, the corresponding increase in fruit production is 23 per cent, 22 per cent, 19 per cent, 9 per cent and 13 per cent, respectively. This shows the superiority of rootstocks associated with vigorous growing trees over those in the dwarfing group.

4. A very high negative correlation existed between growth increment and cropping in case of each scion-stock combination under trial. Therefore, for every increase in fruit production, there was a uniform tendency in each case to decreased rate of vegetative growth reflected in ever decreasing progress in tree-size.

5. The trees on "Kharna Khatta" rootstock are associated with consistently higher fruit production for the entire period of four years as compared with the remaining rootstocks under trial. The results are very highly significant. What is equally important and significant is that this remarkable behaviour of increased fruit production of trees with "Kharna Khatta" as the rootstock, has been attained at the expense of comparatively least decrease in growth rate as shown by the regression coefficients worked out for each scion-stock combination under trial.

6. In view of both tree vigour and cropping, "Kharna Khatta" gave outstandingly the best result as compared to the remaining rootstocks under trial, rough lemon and shaddock coming

7. The trees on Sweet lime and Citron have not only hopelessly fallen behind in tree size but the crops produced in both cases have also been significantly poor. The unsuitability of both these rootstocks for the Marsh Seedless scion has, therefore, been established within a short period of eight years of the life of these trees.

ACKNOWLEDGMENT

The authors are indebted to Sirdar Bahadur Lal Singh, Fruit Specialist, Punjab, now Fruit Development Adviser to the Government of India, for his interest and encouragement throughout the course of these investigations. The Financial Assistance from the Indian Council of Agricultural Research for the carrying out of these investigations is also gratefully acknowledged.

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STUDIES IN HIBISCUS ESCULENTUS (Ladys' finger)

I. CHROMOSOME AND POLLINATION STUDIES

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(Received for publication on 8 August 1945)

(With two Plates)

ACCORDING to Sturtevant [Hedrick, 1919] ladys' finger, gumbo or okra has its origin in tropical Africa. It was known to the Spanish Moors and was used by the Egyptians in the 12th or 13th century. Schweinfurth [1874] found the plant growing perfectly wild on the White Nile. According to *Flora of British India* ladys' finger was also probably originally wild in India as well. De Condolle [1904] however says, 'This opinion seems erroneous, as there is no mention about it in the old Sanskrit literature'.

Ladys' finger or okra is a warm season crop and is grown extensively throughout India. In the Punjab it is one of the most important summer vegetable crops and covers about 1/10 of the area annually put under summer vegetables. According to Purewal [1944] in the Punjab plains two sowings, one early and the other late, are made in a year. For early crop the seed is sown from middle of February to middle of April and for the second or late crop in July. In the Punjab hills the best time to sow okra seed is about the middle of May. Okra seed germinates best at about 85° F. and does not germinate at soil temperature below 68° F., therefore, for early sowings, when the soil temperature is low, seed is sown thickly at the rate of 16 to 24 lb. per acre. When the soil is warm seed should be sown at the rate of 8 to 10 lb. per acre. Okra is sown on ridges 2½ to 3 · ft. apart depending on the variety, the dwarf sorts being spaced closer. The seed is sown thickly about ½ in. deep on top of the ridge in hills, one foot apart, and when the plants are well established they are thinned to one plant in each hill.

From the dietetic point of view leafy vegetables such as spinach, lettuce, cabbage are the most important but according to Purewal [1944] okra pods in the immature edible stage are also a rich source of vitamins A and B and mineral elements like calcium, phosphorus and iron. It is an excellent source of iodine so useful for the control of goiter. The fresh fruit analysis yields about 80 per cent water, 4 per cent protein, 0·4 per cent fat, 12 per cent Nitrogen Free Extract, 1·4 per cent fibre and 1·5 per cent ash.

The okra crop has got a wide usage. In the Punjab the *okra* fruit is mainly used as a cooked vegetable; the mature pod and stem containing fibre are utilized in the paper industry; the plant as a whole is soaked in water and the resulting solution is used as clarifier in the manufacture of *gurh*; and stem and leaves are also used in compost making.

In America okra is used in soups and various culinary preparations in which meats form an important part. Woodroof [1927] states that it is frequently employed for feeding dairy cattle, since there is always an accumulation of unmarketable green pods. He carried out an experiment on feeding okra pods to two Guernsey cows, resulting in an increased yield of milk.

In Africa the use of okra fruit as a vegetable is scarcely known, but it is cultivated rather extensively to provide a substitute drink for coffee. The seeds of the ripened fruit are dried and roasted brown in a covered clay pot to prevent the popping or bursting of the kernels. Then the roasted kernels are ground to a fine powder. The odour of the powder is strongly suggestive of coffee. The drink is prepared like coffee except that the amount of powder used is usually doubled.

Halverson and Naiman [1926] analysed the oil from okra seed and found that mature seeds possess good feeding value in that they consist of 25 per cent protein and 20 per cent oil. This plant being a prolific and vigorous grower in the cotton belt has possibilities of economic importance due to its high oil content and to the feeding value for animals of the high protein meal after the oil is extracted. The composition of okra seed is comparable to cotton seed.

Okra is said to possess considerable medicinal properties. Melegod [1924] thus writes. 'Okra is a well known vegetable cultivated throughout the island (West Indies) but its excellent properties as a nutritious vegetable possessing considerable medicinal properties has been little realized. The fruits in their unripe state are much esteemed as a vegetable and are prepared in various ways. These abound in mild mucilage possessing valuable emollient and demolucent properties and is used in case of catarrhal affection, fevers, irritable state of bladder, etc. In hoarseness and dry irritable state of the throat causing troublesome cough, a soup prepared by boiling down a few unripe *bandakka* (okra pods) in about a pint and half of water and taken after straining and sweetening to taste has proved beneficial in the case of writer. Sometimes a free inhalation of the vapour of this hot *bandakka* soup has been known to act wonderfully on dry troublesome cough and hoarseness. In case where there is difficulty in passing urine, the *bandakka* soup has acted very beneficially. The leaves of *bandakka* plant are used externally as an emollient poultice'.

In accordance with the importance of the crop in the tropical countries of the world, little research work on the classification, culture and breeding of the crop has so far been done. In the U. S. A. Woodroof [1927], Beattie [1918] and Jones and Rosa [1927] have studied the general characteristics of the plant and its cultural requirements. Owen [1910] has conducted some studies on the development of the fruit in the okra plant. Miller [1937] has submitted a preliminary report on okra breeding in Lousiana. In India practically no improvement work has so far been done on this crop. Therefore the studies reported below were made as a preliminary to starting intensive genetical and breeding work.

Chromosome studies

Krenke [1929] reported the haploid chromosome number in okra to be 59,60 or 61. It was, therefore, deemed desirable to ascertain the exact number of chromosomes in this plant.

Three days after protrusion of seedlings at 8 a.m. the root tips were fixed for 24 hours in Navashins fluid to which maltose was added. The air was exhausted by means of an exhaust pump; after fixation the material was washed in tepid water for three hours. The material was embedded by the usual paraffin method. The sections were cut 10μ thick and stained in Iodine Gentian violet, as suggested by De La Cour [1931].

The fixation and staining was found to be satisfactory by this method but when the slides were kept in iodine-iodide for two minutes, the chromosomes in this particular case were found to be destained. The keeping of the slides in iodine-iodide for 30 seconds, however, obviated this defect and gave satisfactory results.

The chromosome counts of all the four varieties i.e. B.1, B.12, B.15, B.19 were made and the number ($2n$) was found to be 120 in each case. The diagrams of the chromosomes of two varieties were drawn with the help of camera lucida at the bench level with $\times 4300$ magnification. The figures drawn (Plate III, figs. 1 and 2) indicate that though there is no difference in the number of chromosomes but there are well marked morphological differences in the chromosomes of these varieties.

Pollination studies

Ladies' finger (*Hibiscus esculentus*) belongs to the natural order Malvaceae. The members of this natural order belong to the group of plants regarded as often cross-pollinated. But so far the floral mechanism and mode of pollination of this plant has not been completely reported, nor any data on the extent of cross and self-pollination are available. Hence these studies together with observations on time of opening of flowers, anther dehiscence, pollen germination, receptivity of stigma, pollen tube growth and development of fruit were undertaken.

Materials and methods

The okra variety B.1 which is one of the most promising strains was selected for pollination studies but for determining the extent of natural crossing, two more varieties, viz. B.14 and B.19 were also grown side by side with B.1. The latter two varieties exhibit contrasting character differences from those of variety B.1 in earliness and shape of fruit, and as such the natural hybrids resulting from these varieties could be singled out with ease in the F1 generation.

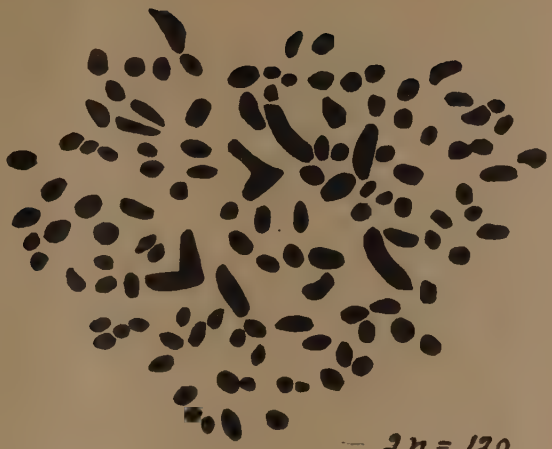
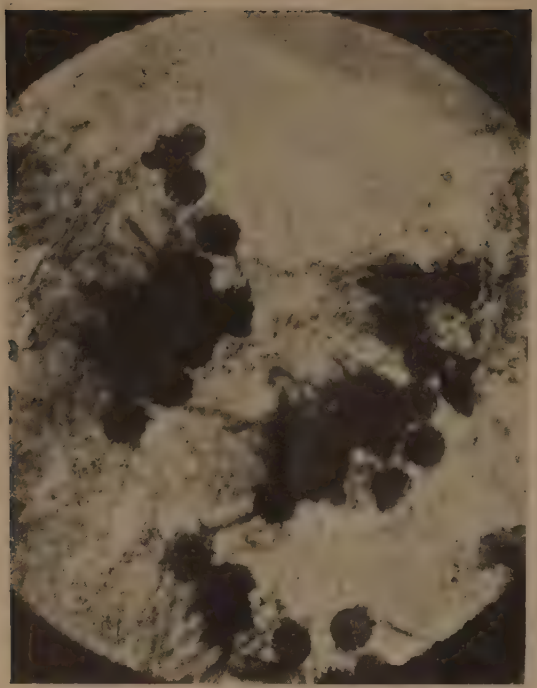


FIG. 1.
Showing the chromosomes in B. 1.

FIG. 2.
Showing the chromosomes in B. 12

FIG. 3(a)
Flower
of
Okra

FIG. 3(b).
Showing
the opening
of 3 flowers
on a single
stem



A

B

C

FIG. 1.

Showing the germination of pollen on stigmatic surface

A—After 5 minutes.

B—After 15 minutes (The tubes have grown sufficiently long)

C—After 30 minutes (Tubes are seen bending towards the styler tract)

Observations and experimental results

Structure of the flower

The flower of the okra plant arises in the axil of the 6th to 12th leaf and upwards depending upon the early or late flowering of the variety. The flowers are hermaphrodite, large and bright yellow in colour.

Calyx. The exterior calyx has from 8-12 linear, caducous bracteoles. The interior calyx spathiform, circumscissile 5-7 fid, not falling off till after the flower opens.

Corolla. Petals five, bright yellow with a crimson centre, connate at the base with the stamina tube.

Androecium. Staminal tube truncate, five toothed at the summit, filaments numerous, anthers reniform, one celled.

Gynaeceum. Ovary multilocular (5-7 celled) each with 3 or more loculicidal ovules. Styles 5, connate below, stigma capitate or subspathulate.

Time of opening of flowers

A flower bud appears in the axil of each leaf above the sixth or eighth leaf depending on the variety. The crown of the stem at this time bears 3-4 undeveloped flowers but later on during the period of profuse flowering of the plant there may be as many as ten undeveloped flowers in a single crown. As the stem elongates, the lower most flower buds open into flowers. Woodroof [1927] stated, 'There may be a period of two, three or more days between the time of development of each flower, but never does more than one flower appear on a single stem'. The observations made by the authors under field conditions, however are not in accordance with those of Woodroof as in a number of cases individual stems were observed to bear two or even three open flowers on the same day. This phenomenon is very well illustrated in Plate III, fig. 3 (*b*).

For determining the proper stage at which the buds open into flowers, 50 buds were selected at random and labelled in the evening at 6·30 p.m. General observtions regarding the colour of the buds and their toughness to slight compression with finger tips were recorded. Physical measurements of the buds such as diameter and length were also taken. On an examination of the selected buds the next morning at 8·30 a.m. it was found that only whitish green, easily compressible buds measuring about $2{\cdot}82 \times 1{\cdot}55$ cm. opened into bright yellow flowers.

For recording the time of opening of flowers 50 buds which were likely to open the next morning were selected on 14-7-43 at 6·30 p.m. and labelled. Observations were recorded in the morning on 15-7-43 as given in Table I.

Table I

The time of opening of flowers on 15-7-43

No. of flowers observed	Time of opening			
	8·20 to 8·25	8·25 to 8·30	8·30 to 8·35	8·35 to 8·40
50	8	25	14	3

From the above data it is seen that all the buds opened into flowers between 8·20 to 8·40 a.m. on a bright sunny day. On cloudy and cold days, however, they opened very late. It was also seen that flowers remain fully open till noon, withering and collapsing towards the sunset.

Mode of opening of flowers

For this purpose ten pale coloured buds likely to open the next morning were closely observed during the night. These observations revealed that around mid-night the covering of the calyx ruptured from one side and corolla lobes enclosing other floral organs protruded. At 5 a.m. the corolla tube had come out altogether leaving the calyx at the base. The petals distended slowly with the rising of the sun and were fully expanded at about 8·30 a.m.

Dehiscence of anthers

The stamens are indefinite, monadelphous with kidney shaped anthers which are dorsifixed to the filaments. The dehiscence of the anthers is transverse and starts 15 to 20 minutes after the opening of the flower. All the anthers of a single flower do not dehisce at the same time but dehiscence starts from the topmost downwards, taking in all 5-10 minutes to complete the process.

Pollen

The pollen grains are large, spherical and frequently adhering owing to the presence of a mucilagenous substance on the surface bright yellow with thick granular exine provided with numerous large, long, conical spines (Plate IV, fig. 1). They varied in size from 672·82μ to 848·48μ with different varieties which in turn exhibited marked differences in the size of the flower, leaf shape, leaf size, stem height, etc.

Germination of pollen in-vitro

A number of experiments were carried out in connection with the germination of pollen of okra *in-vitro*. When okra pollen was placed in moist atmosphere at room temperature it gave only 8·6 per cent germination and on 1 per cent agar plus 55 per cent sugar medium 18 per cent. But the highest and most successful germination was obtained when the extract of stigmatic and stylar tissues was added to the sugar—agar medium as given below.

Medium A—1 per cent agar plus 55 per cent sucrose

Medium B 1 per cent agar plus 55 per cent sucrose plus extract of stigmatic and stylar tissue

TABLE II

The germination of pollen grains in A and B media at room temperature

Treatment No.	No. of grains in each case	Percentage germination	
		Media A	Media B
1	100	14	23
2	100	20	32
3	100	17	29
Average	100	17	28

The figures given in the Table II show a mean increase of 11 per cent in the germination of pollen as a result of the addition of the extracts from stigmatic and stylar tissue. It was also noted that the germination in agar plus sugar medium started earlier and the pollen tubes grew more rapidly than in moist conditions. Some of the pollen grains gave out as many as six pollen tubes, one of the tubes being longer than the remaining ones. Some branching pollen tubes were also noticed while studying the germination of pollen both on stigmatic surface and in artificial media. It may be concluded from the above results that every pore of the pollen grain is a potential germ pore.

Germination of pollen on stigmatic surface. The main object of this study was to determine the probable length of time which the pollen takes to germinate on stigmatic surface. The method of staining smears of stigma in aceto-carmine, as suggested by Anderson and Sax [1934] was tried in the first instance, but was found to be unsatisfactory as the pollen tubes could not be easily differentiated from the papilliate cells of the stigma. The method suggested by Iyengar [1939] was then followed with successful results.

Those okra buds which were due to open in the morning were emasculated the previous evening. In the morning they were hand pollinated and the flowers were then collected after an interval of 5, 15, 30 and 45 minutes. The stigmas were placed in 1 per cent aqueous magenta and after three hours they were transferred to lactic acid and were left there over-night. On the following day, the material was mounted on the slide in a drop of fresh lactic acid. A thick cover glass was placed on it pressing it gently for the purpose of spreading. The examination of the slide under the microscope showed pollen tubes emerging out of the pollen grains. The pollen tubes were quite distinct on account of their purple colour as against light red colour or colourlessness of the rest of the tissue (Plate IV, fig. 1). It appeared that the pollen grains germinated within five minutes after their deposition on the stigma. A further study was made by treating the flowers in the above fashion and collecting the stigmas 2, 3, 4 and 5 minutes after pollination, which showed that pollen grains started germination only about five minutes after their deposition on the stigma.

Pollen tube growth. This study was made to determine the time taken by the pollen tube to traverse the stylar region, in other words, the interval between pollination and fertilization. For this purpose the following experiment was conducted to determine the rate of the pollen tube growth.

A large number of flowers was pollinated with hand at about 8·45 a.m. which is the usual time of dehiscence, and after the successive intervals of each hour, the styles were excised close to the ovary in order to find out whether the pollen tubes (with the generative nuclei) had traversed the stylar length during any particular interval. The results obtained are given in Table III.

TABLE III

The percentage of fruits set by excising the style at different intervals after pollination

Treatment No.	No. of flowers	Time interval after which the style is excised (hours)	Percentage of fruit set
1	100	1	*nil*
2	100	2	23
3	100	3	52
4	100	4	72
5	100	5	83
6	100	6	96

From the above data it is clear that the most actively growing tubes reached the ovule two hours after pollination, while three hours after pollination the percentage of fruit setting increased to 52 per cent indicating a proportionately greater number of pollen tubes traversing the stylar region. At 3 p.m., i.e. six hours after pollination the maximum number of tubes must have reached the ovules as the excision of the style did not have any effect on setting of the fruit. These results show that the time elapsing between pollination and fertilization in okra is very short. Considering 8·45 a.m. as the optimum time of pollination, the first few tubes reached the ovule two hours after pollination and in less than six hours fertilization was complete in all the flowers.

Stigmatic receptivity

The flowers of okra plant remain open for a few hours only. After pollination in the morning, the petals begin to shrival at about noon and late in the afternoon the flowers are turned into a withered, twisted and dying mass. By the following morning these flowers wither, fall off or remain

at the tip of the developing fruit. In order to find out the proper stage of stigmatic receptivity, which could either be before the opening of flowers or after the flowers had opened, premature flowers were bud pollinated in the following manner :

Buds that were to open 24 hours later were emasculated by removing carefully by pointed forceps the sepals, petals and stamens. The stigma at this stage was dull red in colour as against the bright coloured stigma of the fully open flowers. Mature pollen grains of the same variety were then dusted on the stigmatic surface. The pollinated flowers were covered with paper bags which were removed after two days in order to expose the fruit to sun light and to record the percentage of shedding or setting of the fruit as the case may be. The observations recorded showed that no fruit had set, indicating that stigma was not in a receptive condition at least 20 hours before the opening of the flower. It may be argued that the failure of the fruits to set might be due to the injury incidental to emasculation especially when the buds were in such a young stage, i.e. 24 hours before opening of the flower or it may be said that the pollen might have failed to germinate. The chance of 100 per cent failure due to injury are altogether precluded as the buds and floral parts 24 hours before opening of the flower are fairly large to be handled with ease to avoid any injury to the stigma. The lack of setting cannot also be due to the failure of the pollen as the data in Table III clearly show that pollen is viable for at least four hours after dehiscence and probably for a longer interval. Thus, the failure in setting the fruit was actually due to unreceptivity of the stigma.

In the second case the fully open, bright coloured flowers with velvety stigma were pollinated with fresh pollen. This operation resulted in the normal setting of the fruit, showing that the stigma was in a receptive condition as soon as the flowers opened fully.

Pollination

In order to study the mode of pollination the following experiments were carried out :-

1. *Open pollination*. Fifty flowers were tagged for identification and were allowed to pollinate and develop under natural conditions. The setting of the fruit was cent per cent.

2. *Self Pollination (by bagging of the flowers)*. Fifty flowers were covered with paper bags a day before opening to avoid the effect of external agencies like wind and insects in the transference of pollen. The bags were removed the next day after the flowers had shrivelled. The setting of the fruit was cent per cent.

3. *Self pollination (by hand under bag)*. The buds which were expected to open the following morning were bagged in the evening. Next morning out of the bagged buds fifty flowers were labelled and pollinated with brush to ensure proper pollination. The bags were then put on again and removed the next day so that the fruit may develop normally. The setting of the fruit was only 98 per cent.

In the first two treatments the setting of the fruit was cent per cent but in the third case the setting was 98 per cent, showing that there is no significant difference in the percentage of fruit set which means that okra is potentially a self-fertilized crop.

Although the okra flower is mostly self-pollinated but the possibility of cross pollination cannot be ruled out in view of the fact that okra flowers are frequently visited by insects. Our observations showed that honey bees and black ants are the most common visitors. Beattie [1918] stated, 'The common bumble bee is frequent visitor of the flowers of okra, and a single bee one morning was observed to pollinate over 500 flowers, comprising more than 50 samples. In this instance practically every flower in the field was visited and pollinated although no pollen had previously been transferred.' In view of the indefiniteness of the previous writers on the percentage of natural crossings the authors undertook to determine it under natural conditions, by planting varieties B.1, B.14 and B.19 side by side in four replications. These varieties have contrasting characters which could be detected in case of hybrids resulting from them. The seed was collected from open pollinated flowers and sown during the next season. The number of natural hybrids was counted.

TABLE IV

The natural hybrids in different varieties sown adjacant to one another

No.	Variety	Total No. of plants	Hybrids	Percentage of natural crossing
1	B.1	144	14	9·7
2	B.9	130	7	5·4
3	B.14	144	10	7·0
4	B.1	120	5	4·0
5	B.9	140	9	6·4
6	B.14	140	8	5·7
7	B.1	144	10	7·0
8	B.9	144	27	18·75
9	B.14	132	15	11·4
10	B.1	135	13	9·4
11	B.9	144	12	8·3
12	B.14	140	15	10·7
	Total	1,657	145	*Average* 8·75

Table IV shows that natural cross pollination in different plots varied from 4·0 to 18·75 per cent with an average of 8·75 per cent. But there was no significant variation in the percentage of cross pollination in different varieties when plots under each variety were taken collectively. In varieties B.1 and B.14 the percentage of natural crossing was 7·5 and 8·7 respectively.

Development of Fruit

The present investigation was carried out for determining the rate of growth at various stages of development during the growing period and also to ascertain the diurnal effect on the development of okra fruit. It is natural that rate of development would vary in accordance with the prevailing temperatures but the growth increment will remain constant. These determinations were made during the month of June from 16-6-1943 to 29-6-1943 when the hottest weather prevails at Lyallpur.

Forty-five flowers were labelled bearing the date on the day of their opening so that they might be easily distinguished from other fruits and in order to keep a record of their age. The pod length was measured by a meter rod and the pod girth by means of a pair of callipers twice a day at 7-8 a.m. and 6-7 p.m. Similar measurements were also made of the length of the stalks and diameters of the receptacles, until the growth of the fruit ceased.

The measurements recorded showed that the pod obtained its full length 15 days after the opening of the flower. The length of the fruit stalk increased from 1·06 cm. to 2·72 cm., i.e. 2·5 times its original length and the diameter of the receptacle from 1·02 cm. to 2·19 cm., that is, it was nearly doubled in thickness. The examination of the data showed that the pod increased in length at a slow but progressive rate for the first five days and then at a very quick pace for the next two days and afterwards again at a degressive slow rate for the next eight days till the fruit ceased to grow any more. Thus the fruit increased from 0·97 cm. to 15·4 cm. in 15 days. The diameter of the pod increased from 0·69 cm. to 2·29 cm., i.e. about thrice its original diameter at the opening of the flower.

Diurnal effects on the development of fruit. Measurements were taken between 7-8 a.m. and 6-7 p.m. daily comparing the increase in length of the fruit as affected by day and night. The data invariably showed a higher rate of growth at night than during the day. Culpepper and Moon [1941] stated that the rate of growth of okra pod was somewhat more than doubled for each 18°F. (10° C.) rise in temperature at probably all stages of development. But in the present case it was observed that though the temperature at night was lower by 30°F. than that of the day the fruit increased in length more during night than during day. The probable reason that could be assigned to this was that the cells were fully turgid during night on account of comparatively less loss of water through transpiration. Consequently growth of the fruit was more active during the night than in the day.

Time of picking. The observations made on the development of fruit further revealed that the fruit was very small and tender when it was five days old (5·8 cm.). But during the next two days the fruit made a remarkable development (11·3 cm.) while the quality as regards tenderness and colour was not much affected. The above fact indicates that the fruit in this case should be picked when it is 6-7 days old. At that stage of development the quality of fruit is not impaired whereas the yield obtained is nearly double than that of the five day old fruits.

Summary

The Chromosome counts made from the root tips of four varieties of ladys' finger (*Hibiscus esculentus*) showed that 2 *n* number was equal to 120 in each of them.

The flowers of the okra plant usually opened at about 8-20 to 8-45 a.m. The pollen is shed about 10 to 15 minutes after the opening of the flowers and it takes another five to ten minutes for all the anthers of a single flower to dehisce.

The pollen grains are bright yellow, large, spherical with thick conical spines which are round at the base and tapering at the end. The pollen grains usually adhere together on account of the secretion of an oily substance from the exine.

The pollen grains were successfully germinated in an artificial medium of 1 per cent agar plus 55 per cent sucrose at room temperature. The germination started 30 minutes after the pollen grains were placed on the media.

The pollen grains germinated on the stigmatic surface five minutes after their deposition on stigmatic surface.

The stigma is receptive as soon as the flower opens, but, at least 20 hours before opening, the stigma was found to be unreceptive.

The percentage of fruit setting two hours after pollination was 23 while after three hours it was 52 and after six hours it increased to 96 showing thereby that the time lapsing between pollination and fertilization in okra is very short.

The incidence of natural crossing in okra was found to vary from 4·0 to 18·75 per cent, the average being 8·75 per cent.

The pod completed its growth in 15 days and the best time for picking was determined to be 6-7 days after the opening of the flower.

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DISCOVERY OF THE UREDO-STAGE CONNECTED WITH THE AECIDIA SO COMMONLY FOUND ON SPECIES OF *BERBERIS* IN THE SIMLA HILLS

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(Received for publication on 14 October 1946)

(With four Plates)

THE occurrence of aecidia on *Berberis* was first recorded in this country by Barclay [1887]. Later Butler [1905, 1] remarked that the Mussoorie and Jaunsar barberries bear an aecidium entirely different from that found near Simla. He [Butler, 1905, 2] also stated that 'Around Simla *Aecidium Berberidis* undoubtedly occurs on *B. lycium*, and probably also on *B. coriaria* Royle, *B. aristata* D.C., and a species which has been doubtfully referred to *B. umbellata* Wall. It probably also occurs on *B. vulgaris* to the west of Simla, where alone this species is found'. On account of extreme rarity of black rust on wheat and barley in the neighbourhood of infected barberries, he concluded that the aecidium, referred to above, was not allied to black rust of cereals and probably belonged to some other specialized form of the parasite.

East of Simla, Butler identified another interesting species on *B. coriaria*, *B. aristata* and *B. lycium*. It was distinguished from the former by the peculiar deformity of the affected branches and the formation of witch's-broom. The aecidiospores of this species failed to infect cereals and the urenial host remains unknown. Butler, therefore, named the species as *Aecidium montanum*.

Butler and Hayman [1906], Butler and Bisby [1931], Arthur and Cummins (1933), Sydow and Mitter [1935] and Mundkur [1938] also reported the presence of *Aecidium berberidis* on different species of *Berberis* but there is no evidence supported by experimental data to connect it with black rust of cereals or of any of the grasses.

Butler [1918] observed that the barberry aecidiospores in Kumaon could not be got to infect wheat and probably belonged to some other race of the parasite. This was supported by Mehta [1929, 1931 and 1933] who stated that inoculations made on wheat and barley seedlings with aecidiospores from barberries found in the hills gave negative results. Later, he [Mehta, 1940] stated that 'typical aecidia of *Puccinia graminis* have not been found during these studies' and only in the case of *B. lycium*, a specimen collected in May, 1933, was provisionally identified by Butler as belonging to *P. graminis*. The specimen, as stated by Butler, did not quite agree with the European material of *A. berberidis* Gmel., the aecidial stage of *P. graminis* Pers. Other specimens sent to him were identified as belonging to *Aecidium montanum*.

The uredo and teleuto hosts of *Aecidium montanum* remain undiscovered and nothing was known till 1940 of such hosts for the other kind of aecidia that are so commonly found on indigenous species of *Berberis* in the hills of India, one collection of which was provisionally identified by Butler as belonging to *P. graminis*. Mehta [1933] reported that no infection took place on wheat and barley even as a result of inoculations with aecidiospores from the shorter aecidia occurring on *Berberis lycium* and *B. aristata*. As far as the writer can see the material referred to by Mehta belonged to the aecidial stage dealt with in this article.

During the course of investigations on cereal rusts, intensive search was made in the hills for the uredo-stage of the aecidium under reference and in September, 1940, the writer for the first time came across heavily infected plants of *Agropyron semicostatum* Nees growing near diseased bushes of *B. lycium* at Taradevi (altitude 5,000 ft., six miles west of Simla). This was very suggestive of a possible connection between the rust on *Agropyron* and the common aecidium on *B. lycium* recorded by earlier observers.

Extensive observations made in the Simla hills along with laboratory experiments have established this connection, leading to the identification of a new 'Specialized form' of *Puccinia graminis* Pers. Full details are supplied in this article.

It may be stated here that the occurrence of black rust on *Agropyron* is a new record for this country. In England, Europe and the U. S. A. *Agropyron repens* has been found to be infected by *P. graminis secalis* in nature [Stakman and Piemeisel, 1917 ; Mehta, 1923 ; Teterevnikova, 1927 ; Wright and Kirby, 1939]. According to Stakman and Piemeisel [1917] *Agropyron caninum*, *A. cristatum*, *A. smithii*, *A. spicatum* and *A. tenerum* are found infected with *P. graminis tritici* in nature in the U. S. A., and *A. elongatum* is easily infected artificially with that rust while *A. repens* is weakly infected. Waterhouse [1929] observed that *P. graminis tritici* is present on *A. scabrum* throughout the year in Australia.

Methods of study

During the period of study, a large number of collections of infected *Agropyron* showing the uredo and teleuto-stages was made in the neighbourhood of Simla as well as from the higher altitudes of the Simla hills up to Narkunda (9,200 ft. a.s.l.). Teleutospores collected from different places were tested for germination under varying conditions and after different treatments.

Inoculations were made with sporidia on all the species of *Berberis* that are found in the Simla hills and also on (i) *Berberis tinctoria* Lesch. (from the Nilgiris), (ii) *B. umbellata* Wall. (from Darjeeling), (iii) *B. pseudumbellata* Parker (from Tangmarg, Kashmir) and (iv) *B. vulgaris* Linn. raised from seed received from England and the U. S. A., in order to test their susceptibility to the rust of *Agropyron*.

Inoculations with aecidiospores produced artificially on *Berberis* were made on seedlings of three indigenous species of *Agropyron* simultaneously with those of cereals (wheat, barley, rye and oats).

Repeated tests were carried out with the aecidial material occurring in nature on the various species of *Berberis* near Simla.

Morphological and physiological studies of the rust on *Agropyron* were also made including cross inoculations on some of the wild grasses and the cereals.

Germination of teleutospores

As stated above, the teleuto-material of the rust on *Agropyron semicostatum* was first found at Taradevi in September, 1940. There were no uredospores in any sorus at that time. More collections of teleutospores were made in December, 1940, from the same place. During that month infected stems of this grass were also noticed at village Sanahan in east Simla but, as at Taradevi, uredospores could not be found.

In the following year when Taravedi was visited on 29 June, 1941, the grass was free from rust but pycnia were visible on leaves of *Berberis lycium*. A month later bushes of *B. lycium* were found to bear aecidia and within ten feet of those bushes the grass was infected with the uredo-stage. By the end of September the rust on the grass had all passed into the teleuto-stage.

Again in 1942, there was no infection on plants of *Agropyron* on 25 June but pycnia had started appearing on bushes of *B. lycium*. A month later aecidia had been formed on *B. lycium* and the grass had traces of rust. Early in August infection was well-advanced on the grass and most of the stems were found heavily rusted.

In greenhouse cultures teleutospores were formed on infected leaves within two weeks of rust appearance which shows that the uredo-stage is of a very short duration. This was supported by field observations.

Detailed information regarding teleutospore collections made from time to time, their storage, treatment and germination is given in Table I.

TABLE I

Detailed information regarding the collection of teleutospores from Agropyron semicostatum *Necs from different places from time to time, their storage, treatment and germination*

No.	Date and place of collection, its storage, etc.	Further treatment	Percentage germination	Remarks
1	From Taradevi on 15-9-40 and stored in :			
	(i) a room at Simla	(*a*) Spores floated on tap water after soaking straw overnight	30	(*a*) Germination was tested in shade soon after collection. Spores started germinating in 48 hours
	(ii) in refrigerator at 40-50° F.	(*b*) Spores floated on tap water after one wetting and drying, each for one day, followed by soaking straw overnight	60	(*b*) Germination was tested on 17-94-0 in shade. Spores started germinating in 48 hours
		(*c*) Straw dried and soaked several times	60—160	(*c*) Germination was tested several times during October, 1940, and July, 1941. Spores started germinating in 48 hours and in some cases in 6 hours
		(*d*) Straw dried and soaked several times	10	(*d*) Germination was tested in August, 1941
		(*e*) Straw soaked in water overnight	5	(*e*) Tested in September, 1941. Germination after 72 hours
		(*f*) Straw soaked in water overnight	None	(*f*) Germination was tested in October, 1941
2	From Taradevi on 29-6-41; formed in September-October, 1940 and exposed to natural conditions	(*a*) Straw soaked in water overnight	80	(*a*) Germination was tested soon after collection
		(*b*) Soaked in water overnight	90—100	(*b*) Germination was tested several times in July, 1941, at room temperature
3	From Sanahan on 15-12-40, and stored in a room at Simla	(*a*) Straw soaked in water overnight soon after collection	75	(*a*) Germination was tested soon after collection. Spores germinated in 24 hours
		(*b*) Straw soaked and dried several times	75—100	(*b*) Germination was tested several times during January-July, 1941. Spores germinated in 6 hours in some cases
		(*c*) Straw soaked and dried several times	10	(*c*) Germination was tested in August, 1941
		(*d*) Straw soaked in water overnight	None	(*d*) Tested in September, 1941
4	From Sanahan on 16-4-41. Formed in September-October, 1940 and exposed to natural conditions	Straw soaked in water overnight	90	Germination was tested soon after collection
5	The same as above, collected on 15-7-40	Straw soaked in water overnight	33	Tested soon after collection. Germination in 36 hours
6	From Taradevi on 23-7-41; just formed	Straw soaked in water overnight	Traces	Tested soon after collection. Germination in 5 days
7	From Taradevi on 9-9-41; stored in—			
	(i) a room at Simla	(*a*) Straw soaked in water overnight	40	(*a*) Tested soon after collection. Germination in 48 hours
	(ii) refrigerator at 40-50° F.	(*b*) Straw dried and soaked several times alternately	50—100	(*b*) Tested several times during October, 1941 to May, 1942; Spores germinated in 6-48 hours
8	From Sanahan on 30-9-41; stored in—			
	(i) a room at Simla	(*a*) Straw soaked in water overnight	33	(*a*) Tested soon after collection
	(ii) refrigerator at 40-50° F.	(*b*) Straw dried and soaked several times alternately	50—100	(*b*) Tested several times during October, 1941 to May, 1942. Spores germinated in 6-48 hours

No.	Date and place of collection, its storage, etc.	Further treatment	Percentage germination	Remarks
9	From Theog (alt. 7,500 ft.) on 4 October, 1941	Straw soaked in water overnight	50	Tested soon after collection. Spores germinated in 48 hours
10	From Mattiana (alt. 7,900 ft.) on 5-10-1941	Straw soaked in water overnight	60	Tested soon after collection. Spores germinated in 48 hours
11	From Narkunda (alt. 9,200 ft.) on 6-10-41	Straw soaked in water overnight	60	Tested soon after collection. Spores germinated in 48 hours
12	From Arki (alt. 3,000 ft.) on 15-12-41	Soaked in water overnight	75	Tested soon after collection. Spores germinated in 24 hours
13	From Jaku (Simla) on 22-3-42.	(*a*) Straw soaked in water overnight	60	(*a*) Germination was tested soon after collection. Spores germinated in 48 hours
		(*b*) Straw soaked, dried and soaked in water for 24 hours, 24 hours and 3 hours, respectively	100	(*b*) Tested soon after collection. Spores germinated in 8 hours
14	From Taradevi on 15-4-42. Formed in the previous year and exposed to natural conditions	Straw soaked in water overnight	80	Tested soon after collection. Spores germinated in 24 hours
15	From Sanahan on 20-4-42. Formed in the previous year and exposed to natural conditions	Straw soaked in water overnight	90	Germination was tested soon after collection. Spores germinated in 24 hours
16	From Theog on 29-5-42 on previous year's straw	Straw soaked in water for 3 hours	70	Tested soon after collection. Spores germinated in 8-10 hours
17	From Mattiana on 30-5-42 on previous year's straw	Do. . . .	80	Do.
18	From Narkunda on 1-6-42. from previous year's straw	Do. . . .	70	Do.

Although teleutospores germinated soon after formation without any special treatment, better results were obtained as the material matured either by exposure to weather or by alternate drying and wetting to simulate natural conditions, as shown in Table I. Soon after their formation in July-September, the germination of teleutospores was from trace to 40 per cent rising gradually to 60-100 per cent during October-July. In August-September when the material was nearly a year old, its viability gradually diminished to *nil*. Even storage at 40°-50 F. inside a frigidaire did not prolong the life of teleutospores beyond a year or so.

Freshly formed teleutospores required a longer period of soaking in water than the mature ones for germination to commence. Minimum time taken by the latter was found to be six hours.

(i) Cardinal temperatures for the germination of teleutospores

From information available in literature it appears that teleutospores of *Puccinia graminis* do not germinate and produce sporidia above 25°C. Melhus, Durrell and Kirby [1920] stated that sporidia formation may occur only between 5° and 25°C. but seems most profuse at 20°C., while Lambert [1929] observed that the teleutospores germinated well at 12° 18°C. but most consistently at the latter temperature. Verwoerd [1931] found that temperatures above 22°C. were unsuited for the germination of teleutospores of black rust and infection of barberries in South Africa. According to Cotter [1932] teliospores of *P. graminis* rarely if ever germinate and produce and liberate sporidia at temperatures higher than 26° C. and a range of 12° to 21°C. gave the most favourable results. As recorded by Mehta [1940] all tests made in this country with teleutospores of *P. graminis tritici* between 50° and 65°F. gave the best germination.

In order to determine the range of temperature that is congenial for the germination of teleutospores of the rust under study, as well as to see in which season temperature conditions prevailing in Simla are suited for their germination, tests were made twice a month in the Stephenson's screen and a record of temperature was kept. Results are given in Table II.

TABLE II

Germination of teleutospores of black rust of *Agropyron* under different conditions of temperature prevailing at Simla. All tests were made in the Stephenson's screen.

Period of floating teleutospores on water.	Percentage germination	Average temperature in degrees F.		Remarks
		Minimum	Maximum	
Material was collected from Taradevi on 15-9-40 and stored in a room at Simla :				
8—10 October, 1940	60	57	68	
15—17 October, 1940	60	55	68	
1—3 November, 1940	75	53	66	
15—17 November, 1940	70	44·5	62·5	
1—3 December, 1940	100	43	59	
15—17 December, 1940	90	40	53·5	
6—8 January, 1941	0*	31	40	* Simultaneous tests in the heated greenhouse (48°—65° F.) gave 80—90 per cent germination
16—20 January, 1941	0*	29†	40	
1—2 February, 1941	90	39	53	
8—10 February, 1941	0*	28	40	† Minimum temperature was 26° F. on 19 January
14—16 February, 1941	100	39	48	
1—3 March, 1941	100	42	62	
15—16 March, 1941	90	50	71	
1—3 April, 1941	100	48	68	
15—16 April, 1941	100	56	74	
1—4 May, 1941	50	68	88	
15—17 May, 1941	70	56	70	
2—4 June, 1941	60	53	68	
15—17 June, 1941	50	60	72	
1—4 July, 1941	40	60	69	
15—17 July, 1941	10	58	70	
Material collected from Sanahan on 15-12-40 and stored in room at Simla :				
18—20 July, 1941	70	58	70	
1—4 August, 1941	30	60	68	
15—17 August, 1941	10	64	68	
1—4 September, 1941	T*	56	70	* Low viability was probably due to age of material, otherwise the temperature appears to be suitable for germination
15—18 September, 1941	0*	60	79	
Material collected from Taradevi on 29 September, 1941 :				
1—4 October, 1941	40‡	56	70	‡ Percentage germination soon after collection
15—17 October, 1941	50	52	72	
1—4 November, 1941	50	48	68	
15—17 November, 1941	60	44	63	
1—4 December, 1941	50	50	70	
15—17 December, 1941	75	42	63	
1—4 January, 1942	80	34	52	
14—20 January, 1942	0+*	28	40	+* Simultaneous tests at 50°-54° F. gave 60 per cent germination on 16 January
19—21 January, 1942	10**	30	50	** 50 per cent germination was noticed at 42°—50° F.
9—11 February, 1942	100	40	52	
20—22 February, 1942	0+*	30	38	
2—4 March, 1942	90	40	60	
15—17 March, 1942	80	48	70	+*50 per cent. germination was noticed at 42°—50° F.
1—4 April, 1942	75	53	74	
15—17 April, 1942	90	43	59	
1—3 May, 1942	90	62	81	
14—16 May, 1942	80	53	72	
4—6 June, 1942	70	66	86	

From the data supplied in Table II it is clear that teleutospores of black rust of *Agropyron* germinate very well between 40° and 88° F. Germination tests carried out under controlled conditions in an incubator also show that satisfactory germination takes place between 40° and 90° F. and practically none below and above that range. It is interesting to note that it was found impossible to germinate teleutospores of wheat, oats and rye stem rusts outside 45°–70° F.

It is also apparent from Table II that temperature is generally suitable for the germination of teleutospores of the rust under study throughout the year at Simla, except during winter when the temperature at times drops below 40° F. It may, however, be pointed out that, besides temperature, saturated atmospheric humidity and presence of young leaves are important factors in the successful infection of barberries. Since these conditions are present in abundance during the rainy season (June-September) in the Simla hills, infected barberries are so common at that time.

(ii) *Influence of exposure to high temperatures on the viability of teleutospores*

The viability of teleutospores may be greatly affected by exposure to high temperatures subsequently to their formation. Stakman, Kirby and Thiel [1921] found that teliospores of stem rust formed in the northern States of the United States, when kept in the south, produced no infection on barberries, which are commonly infected in the north. Lambert [1929] also observed that teleutospores formed during May and June in States like Texas, Oklahoma, Southern Kansas, etc., are killed by exposure to hot summer in the months of July-September. According to Stakman [1934] the absence of infection on barberries in the far south of U. S. A. is due to the loss of viability of teliospores during the hot summers. Novotelnova [1935] observed that teleutospores of *Puccinia graminis avenae* are killed after exposure to 30° C. for 24 hours. Mehta [1940] remarked that it is very unlikely for the teleutospores to retain their viability after exposure to summer heat in the plains of India, even if germinable at the time of formation.

It has been found that teleutospores of *Agropyron* rust formed in September-October and exposed to natural conditions of weather at Simla are viable in June-July of the following year (see Table I). This shows that the temperature conditions prevailing in winter, spring and summer at Simla do not affect adversely their germinability.

Influence of exposure to higher temperatures on the viability of teleutospores of *Agropyron* rust was experimentally determined by keeping viable material in a water bath at different temperatures between 90° and 120° F. for 6 to 24 hours. Germination of the heated material and that of control was tested at 50°–65° F. It was found that exposure for 24 hours at 90°–100° F. reduced the germination from 90 to 60 per cent. Only 40 per cent germination was observed after 24 hours' exposure at 100°–110° F. and 20 per cent at 110°—120°. No viability was left after the material was exposed at 110°–120° for 48 hours. It is interesting to note that teleutospores of wheat stem rust lost all viability after exposure to 100°–110° for 24 hours and 110°—120° for 18 hours.

One hundred teleutospores were studied and found to measure 38·59–56·75 × 13·62–20·43 μ and the size of the largest number of spores was found to be 45·4 × 18·16 μ.

Germinating teleutospores taken from *Agropyron semicostatum* are photographed in Plate I, fig. 1.

Inoculations on species of *BERBERIS*

A large number of inoculations was made with sporidia of this rust on different species of *Berberis* growing commonly in the neighbourhood of Simla, viz. *B. lycium* Royle, *B. aristata* DC and *B. coriaria* Royle. In addition, inoculations were made on *B. petiolaris* Wall. found in a restricted area at Narkunda (alt. 9,200 ft., 40 miles east of Simla), *B. pseudumbellata* Parker obtained from Tangmarg (alt. 7,200 ft. in Kashmir), *B. umbellata* Wall. found at Singlila in Darjeeling and *B. tinctoria* Lesch. obtained from the Nilgiris. *B. vulgaris* Linn., known to be most susceptible to all the 'Specialized forms' of *Puccinia graminis* Pers. was also inoculated several times, simultaneously with other species. It may be stated here that true *Berberis vulgaris* Linn. does not occur in India [Schneider, 1905]. For that reason, plants raised from seed obtained from England and the U. S. A. were used.

FIG. 1. Germinating teleutospores of *P. graminis agropyri* ×300.

FIG. 2. Arrangement for inoculating young shoots and leaves of barberry bushes with sporidia.

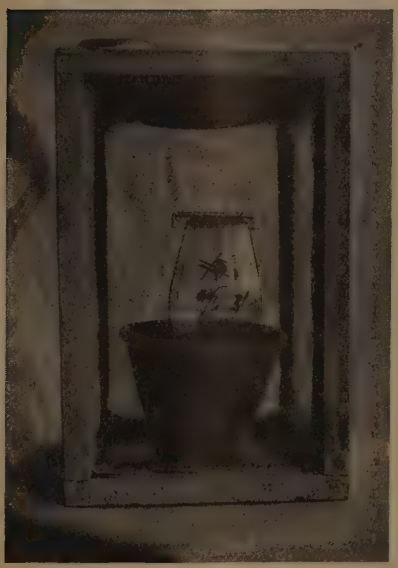

FIG. 3. Arrangement for inoculating plants of *Berberis* grown in pots.

FIG. 4. Leaf of *Berberis lycium* Royle, 10 days old when inoculated on the bush under natural conditions. (×1½).

FIG. 1. Young shoot of *B. Lycium* Royle, 3-5 days old at the time of inoculation in the greenhouse (natural size).

FIG. 2. Leaf of *B. aristata* DC. seven days old when inoculated on the bush under natural conditions (natural size).

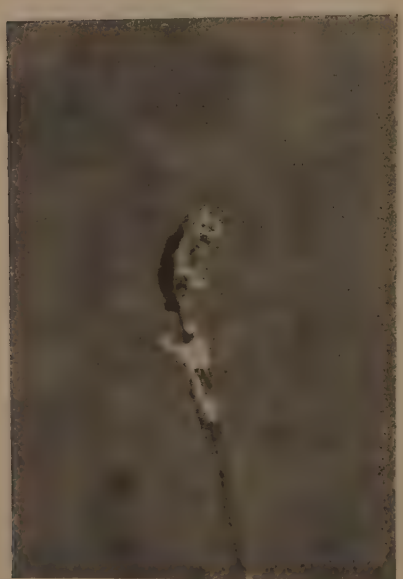

FIG. 3. Leaf of *B. coriaria* Royle five days old at the time of inoculation in the greenhouse (natural size).

FIG. 4. Leaf of *B. umbellata* Wall, four days old at the time of inoculation in the greenhouse (× 2).

Inoculations were made on all the species in the open, under natural conditions, as well as in the greenhouse. For *B. lycium* and *B. aristata* young leaves and shoots on bushes growing in the laboratory compound were inoculated. The shoot was covered with butter paper bag before the leaves appeared, in order to safeguard against wind-borne infection. Each leaf was marked on the day it started unfolding with dated paper label for the determination of its age at the time of inoculation. The paper bag was removed before inoculation and the young shoot and leaves well sprayed with tap water in the morning and covered with a broad glass tube closed at one end. The glass tube was lined with wet blotting paper and the other end plugged with wet cotton wool after inserting the young shoot to make it turgid for inoculation. The young shoot was uncovered in the evening and inoculated with a platinum loop dipped in a suspension of germinating teleutospores in fresh tap water. Pieces of straw bearing teleutosori were stuck in the wet blotting paper lining and the glass tube and cotton wool plug replaced. The whole apparatus was supported with cotton thread on other shoots of the bush as shown in Plate V, fig. 2. On the fourth day (during this period the inoculated shoot was shaded from direct sun with a piece of cloth), the glass tube was removed and replaced with a butter paper bag and a label was put on it indicating the date of inoculation. This is also shown in the photograph. The bag was removed after the appearance of pycnia to let the insects visit the infected parts.

Fresh leaves of other species were inoculated in the open on plants grown in pots. The technique of inoculation was the same as described by Mehta [1940], and illustrated in Plate V, fig. 3. The glass case and the chimney were removed on the fourth day from the date of inoculation and the inoculated parts covered with butter paper bag which was taken off when the pycnia appeared. The plants were screened from direct sun during the period they remained under the glass case.

The same method of inoculation was employed in the greenhouse tests except that it was not necessary to put on the butter paper bag after the plants were uncovered.

Successful infection, resulting in the formation of aecidia on susceptible species, was obtained under natural conditions throughout the year at Simla (temperature 40°—85° F.). Generally, pycnia appeared in 7—10 days after inoculation and aecidia within 15—20 days. At lower temperatures, as expected, the incubation period was longer and aecidia were formed in 20—30 days. Aecidia formed under natural conditions were short and accompanied by marked swelling of the leaf, while those produced in the greenhouse were long and without any swelling of the affected parts. Mains [1924] stated ' Oftentimes in the greenhouse the peridia of aecidia do not open but project out as long cylindrical column from which no spores are shed '.

The results of inoculations made on different species of *Berberis* are summarized below :

(i) *Berberis lycium* Royle is found very commonly in the neighbourhood of Simla. Seedlings as well as older plants have proved to be heavily susceptible. Fresh leaves of seedlings and plants raised from root-wood have produced aecidia up to the age of 16—18 days in the greenhouse but only 12—14 days when inoculated on bushes under natural conditions. Infection occurs on leaves, stems, spines and petioles, although heaviest infection was noticed on the leaves, probably because of larger surface being exposed to rust attack. Infected leaves are photographed in Plate V, fig. 4 and Plate VI, fig. 1.

Reaction of this species to other ' Specialized forms ' of *Puccinia graminis* as well as its distribution in this country have been supplied by Mehta [1940] and need not be repeated here.

(ii) *B. aristata* DC., also found commonly in Simla and the higher altitudes of the Simla hills, showed moderate infection. Leaves up to the age of 8—10 days in the case of young plants raised from seed and 6—8 days in plants raised from root-wood produced aecidia in the greenhouse, while under natural conditions only leaves up to the age of 6—8 days got infected on the bushes. A photograph of an infected leaf is reproduced in Plate VI, fig. 2.

For the reaction of this species to other ' Specialized forms ' of *Puccinia graminis* as well as its distribution in this country, reference may be made to Mehta [1940].

(iii) *B. coriaria* Royle does not occur near Simla proper and in the lower altitudes of the Simla hills. It is common between Mattiana (7,500 ft.) and Narkunda (9,200 ft.). Fresh leaves up to the age of 10—12 days got infected in the greenhouse on seedlings and young plants raised from seed. In plants raised from root-wood, on the other hand, aecidia were produced on leaves 8—10 days old in the greenhouse and 6—8 days old when plants were inoculated under natural conditions in the open. Infection was moderate to heavy in every case. Infected leaves are photographed in Plate VI, fig. 3.

Mehta [1940] has described the reaction of this species to other ' Specialized forms ' of *P. graminis* and supplied its distribution in India.

(iv) *B. petiolaris* Wall. [Syn. *B. pachyacantha* Koehne, as described by Parker [1924], and *B. vulgaris*, var. 1 *vulgaris* proper according to Hooker (1875)], is not found near Simla. It grows in a restricted area at Narkunda (alt. 9,200 ft.).

Some inoculations were made only on fresh leaves produced on plants raised from root-wood because seed of this species was not available. No infection took place even on very young leaves, 2-4 days old, in the greenhouse, although fresh leaves of *B. lycium* inoculated simultaneously got heavily infected.

There is no information in literature on its reaction to *P. graminis* in other countries. Mehta [1940] observed that it is not infected by sporidia of *P. graminis tritici* in India.

Butler and Bisby [1931] reported the occurrence of aecidia of *P. graminis* Pers. on *B. vulgaris* in the Himalayas, but as already stated, true *B. vulgaris* Linn. is not found in India.

(v) *B. pseudumbellata* Parker [Parker, 1924] does not occur in the Simla hills. It is found in Kashmir near Tangmarg where Stewart collected aecidia on it which were identified by Arthur and Cummins [1933] as belonging to *P. graminis* Pers.

For want of a larger number of plants only a few inoculations could be made resulting in the formation of pycnia on two days old leaves on plants raised from root-wood. Fresh leaves of *B. lycium* inoculated simultaneously got heavily infected and produced aecidia. Work could not be done on seedlings of this species because good seed was not available.

There is no information in literature on its reaction to any ' Specialized form ' of *P. graminis* Pers.

(vi) *B. umbellata* Wall. also is not found in the Simla hills and work was done on plants raised from seed and root-wood obtained from Singlila in Darjeeling. Light infection was produced in the greenhouse on 4—6 days old leaves of seedling and young plants grown from seed resulting in the formation of aecidia on some of them. A photograph of a four day old leaf infected in the greenhouse is reproduced on Plate VI, fig. 4. Only pycnia were formed on leaves up to the age of four days in plants raised from root-wood.

The reaction of this species, from information available in literature, to other ' Specialized forms ' of *P. graminis* and its distribution in India have been supplied by Mehta [1940].

(vii) *B. tinctoria* Lesch. was obtained from the Nilgiris because it does not occur in the Simla hills. Aecidia were produced in the greenhouse and outside on leaves up to the age of six days on seedlings and young plants grown from seed and on leaves 4-5 days old on plants raised from root-wood. The infection was light to moderate.

A photograph of a four day old leaf infected under natural conditions is reproduced in Plate VII, fig. 1.

There is no information in literature regarding its reaction to *P. graminis*.

According to Hooker [1875] and Fyson [1932], *B. tinctoria* Lesch. is a variety of *B. aristata* but Schneider [1905] has put it as a separate species. It is found only in the Nilgiris and the Palni hills in this country.

(viii) *B. vulgaris* Linn. was raised from seed obtained from England and the U. S. A. because, as already stated, true *B. vulgaris* Linn. does not occur in India. Results of inoculations made on fresh leaves of this species with sporidia of black rust of *Agropyron* are very interesting because, contrary to expectations, no infection was produced even on leaves two days old on the seedlings.

FIG. 1. Leaf of *B. tinctoria* Lesch., four days old at the time of inoculation on plants raised from root-wood and growing under natural conditions at Simla laboratory. ($\times 1\frac{1}{2}$).

FIG. 2. Infected *B. lycium* and rusted *Agropyron samicostatum* growing together at Sanahan.

FIG. 3. Infected leaves of *B. lycium* found near Simla. (natural size).

FIG. 4. Infected leaves of *B. lycium* found near Simla. (natural size).

FIG. 1. Infected leaves of *B. aristata* found near Simla. (natural size).

FIG. 2. Deformed shoot with leaves heavily infected with *Aecidium montanum* (slightly reduced).

FIG. 3. Infected leaves of *B. coriaria* found on bushes at Narkunda. Two leaves on the left bear *Aecidium montanum* (natural size).

In a large number of tests made on seedlings as well as on plants up to six years old not a single leaf got infected, and even pycnia were not formed on any of them. All the leaves remained perfectly healthy. Fresh leaves of *B. lycium* inoculated simultaneously in every test got heavily infected.

It is well-known that *B. vulgaris* Linn. is heavily infected by all the 'Specialized forms' of *P. graminis*. Arthur [1929] has stated that *B. vulgaris* is a favourable host for all except one of the races recognised in the sporophytic stage. For the one exception, viz., *P. graminis phlei-pratensis*, a congenial aecial host is unknown, for this race differs from others in not infecting *Berberis vulgaris* to any extent. Verwoerd [1931] successfully infected this species with teleutospores of *P. graminis tritici*, *P. graminis avenae* and *P. graminis secalis* in S. Africa. Cotter [1932] obtained infection of leaves 12-15 days old several times in the U. S. A. He stated that '*Berberis vulgaris* is generally supposed to be the species of barberry most susceptible to the attack of *Puccinia graminis*'. Levine and Cotter [1932] have quoted this species to be heavily susceptible to *P. graminis tritici*. According to Mehta [1940], leaves up to the age of 12 days are heavily susceptible to sporidia of *P. graminis tritici* in this country.

The significance of the failure of infection of *Berberis vulgaris* Linn. alone by the sporidia of the rust under study on its classification is fully discussed later in this article.

One hundred aecidiospores were measured from *B. lycium* infected in the greenhouse and found to range from 20·43—27·24×17·02—22·7μ (average 23×19μ). Aecidia are hypophyllous and measure about 10—14 mm. in length when produced in the greenhouse and 2-3 mm. if formed under natural conditions in the open.

Aecidiospores of *P. graminis tritici* produced on *B. lycium* in the greenhouse under indentical conditions measured 18·16—22·7×15·89—20·43μ (average 20×17μ) and aecidia were 12-14 mm. in length.

Inoculations with Aecidiospores artificially produced

Inoculations made on *Agropyron semicostatum*, *A. longearistatum*, and *A. repens*, var. *aristatum* (Kashmir) with aecidiospores produced artificially on species of *Berberis* described above resulted in the formation of uredo-sori in every case.

Simultaneous inoculations made on wheat (*Triticum* spp.), barley (*Hordeum vulgare*), rye (*Secale cereale*) and oats (*Avena sativa*) with aecidiospores so produced in the laboratory and with uredospores obtained therefrom on *Agropyron* gave negative results. The varieties of wheat, barley, rye and oats on which inoculations were made are :

(i) Wheat :
1. *Triticum compactum* var. Little club
2. *T. vulgare* vars. Marquis and Agra local
3. *T. durum* var. Spelmar
4. *T. monococcum* var. Einkorn
5. *T. dicoccum* var. Khapli

(ii) Barley:
1. *Hordeum vulgare* var. Agra local

(iii) Rye :
1. Petkusar
2. Colourless
3. Dakold
4. Rosen
5. A susceptible variety obtained from Agricultural College, Lyallpur

(iv) Oats :
1. White Tartar
2. Joanette
3. Richland
4. Agra local

Observations on infected Barberries and rusted *AGROPYRON* in the Simla Hills

Search for the rusted grass near infected barberries was continued at other places in the Simla hills after September, 1940, when both the hosts were first noticed growing together at Taradevi. Infection on bushes of *B. lycium* and *B. aristata* is quite common during June—August near about Simla and in most cases rusted *Agropyron* was met with in their neighbourhood in August—September. At some places infected barberries were found growing along with plants of *Agropyron*. Plate VII, fig. 2 shows the photograph of one such bush found at Sanahan (a village near Simla) on 26 August, 1941. There were old aecidial cups on *B. lycium* and the grass had uredo and teleuto pustules on the stems.

Aecidia have been noticed during May—July on *B. aristata* in the higher altitudes at places like Kufri (8,200 ft.), Theog (7,500 ft.) and Mattiana (7,900 ft.) but the leaves are never so heavily infected as those of *B. lycium*. In most cases straw of *Agropyron* with teleuto-sori was found near diseasde bushes. Inoculations made on Agra local wheat, barley, oats, rye and *Agropyron semicostatum* with aecidiospores from *B. lycium* and *B. aristata* found near Simla as well as at higher altitudes resulted in the infection of *Agropyron* only.

At Theog and Mattiana, plants of *Agropyron* with uredo and teleuto pustules were found near infected barberries in the first week of October, 1941, when those places were visited. Leaves of *B. lycium* and *B. aristata* found infected on the bushes are photographed on Plate VII, figs. 3 and 4 and Plate VIII, fig. 1.

Two kinds of aecidia were observed on *B. coriaria* at Narkunda (altitude 9,200 ft.) during May—June; one type resembling *Aecidium berberidis* (?) and the other answering to the description of *Aecidium montanum* Butl. It appears that leaves bearing the former either get infected in September—October but produce aecidia not before the following spring on account of very low temperature during winter at that altitude, or, the teleutospores over winter and germinate and produce infection early in spring. Nothing can be said for *A. montanum*. Leaves of *B. coriaria* bearing the two kinds of aecidia are photographed on Plate VII, fig. 3 and a deformed shoot with leaves heavily infected with *Aecidium montanum* is shown in Plate VII, fig. 2. Inoculations made on the spot with aecidiospores from both kinds of aecidia separately, gave negative results on wheat, oats, rye and *Agropyron semicostatum* in the case of *Aecidum montanum* but resulted in the production of uredo pustules only on *Agropyron* with the other kind of aecidia, resembling *A. berberidis*. These inoculation were repeated several times in the laboratory at Simla but with the same results. *Agropyron* alone was infected with spores from un-deformed leaves only. This explains the failure of infection all these years on wheat and barley seedlings with aecidiospores occurring in nature as reported by Mehta [1933, 1940].

Aecidiospores from both kinds of aecidia remained viable for nearly a month at room temperature (60°—70° F.) at Simla.

Measurements of aecidia and aecidiospores taken from *Berberis coriaria* bushes are supplied in Table III.

Table III

Dimensions of Aecidia and Aecidiospores of *Aecidium montanum* and *A. berberidis* (?) found in nature on *Berberis coriaria* and of *A. berberidis* (?) found on *B. lycium*

Type of Aecidum	Length of Aecidia	Aecidiospores	
		Size limits in μ	Average in μ
B. coriaria			
1. *A. montanum*	2—3 mm.	24·97—34·05 × 18·16—27·24	29·51 × 24·97
2. *A. berberidis* (?)	1—2 mm.	19·29—29·51 × 17·02—22·7	24·43 × 19·87
B. lycium			
1. *A. berberidis* (?)	1—2 mm.	19·29—27·24 × 15·89—22·7	24·97 × 19·29

The Uredo-stage

Wherever found, Agropyron was heavily infected ; stems, leaves and ears being involved. Infection with uredo-stage was never so heavy as with the teleuto-stage.

A culture of the rust under study has been maintained in the greenhouse ever since it was first collected at Taradevi. The incubation period was found to vary between 8 and 15 days according to weather.

In general, the shape of uredospores is similar to that of uredospores of black rust on wheat oats or rye. If, however, a large number of spores is measured from cultures grown on their congenial hosts, it is found that there are significant differences in the size of uredospores of the four rusts. For the sake of comparison, the dimensions of uredospores of each of these rusts is given in Table IV. The results were obtained from the study of one hundred spores of each rust as represented by a mixture of six physiologic races of *Puccinia graminis tritici*, four races of *P. graminis avenae*, as reported to occur in this country by Mehta [1940], a culture of *P. graminis secalis* originally started from material obtained from Cambridge, England and a culture of the rust under study on seedlings of *Agropyron semicostatum*. All the spores were taken from greenhouse cultures grown under identical conditions.

Table IV

Dimensions of uredospores of *Puccinia graminis tritici*, *P. graminis avenae*. *P. graminis secalis* and the *Agropyron* rust taken from cultures maintained in the greenhouse

Specialized form	Size limits in μ	Average in μ
P. graminis tritici	22—33×13·2—22	28×17·6
P. graminis avenae	17·6—37·4×11—19·8	26·4×17·6
P. graminis secalis	24·97—34·05×13·62—18·16	28·37×15·89
Agropyron rust	20·43—31·78×12·48—18·16	26·1×14·7

It is clear from the data supplied in Table IV that uredospores of *Agropyron* rust are smallest out of all the four rusts studied.

Like others, the uredospores of *Agropyron* rust have four equatorial germ-pores and there are no mesospores or paraphyses.

In general appearance the pustules of the four rusts are similar. The shape is usually oval to broadly linear but when the infection is heavy the sori coalesce with one another and form long pustules. In greenhouse cultures on leaves of seedlings the pustules of *Agropyron* rust are linear and measure 2—3 mm. when ripe.

Uredospores from pure cultures of the *Agropyron* rust were put on seedlings of Agra local wheat barley, oats and Lyallpur rye but no infection was produced on any of them. Differential hosts of *P. graminis tritici* [Stakman & Levine, 1922]. *P. graminis avenae* [Stakman, Levine and Bailey, 1923] and *P. graminis secalis* [Levine and Stakman, 1923] were next inoculated but the results were negative.

A dozen representative wild grasses were also inoculated with uredospores and the results are supplied in Table V.

TABLE V

Results of inoculations with uredospores of black rust of Agropyron semicostatum *on seedlings of some wild grasses*

Serial No.	Name of grass	No. of tests	No. of leaves		Degree of Infection
			inoculated	infected	
1	*Bromus patulus*	2	20	20	Heavy
2	*Brachypodium sylvaticum*	2	20	0	No infection
3	*Avena fatua*	2	18	0	Do.
4	*Dactylis glomarata*	2	24	0	Do.
5	*Agrostis alba*	2	20	0	Do.
6	*Poa pratensis*	2	25	0	Do.
7	*Phalaris minor*	2	22	0	Do.
8	*Festuca ovina*	2	20	0	Do.
9	*Panicum Crus-galli*	2	24	0	Do.
10	*Aira flexuosa*	2	22	0	Do.
11	*Agropyron repens*	2	20	20	Heavy
12	*A longearistatum*	2	20	20	Do.
13	*A. semicostatum*	2	20	20	Do.

Seed of Nos. 1, 2, 3, 7, 12 and 13 were collected by the writer near Simla ; Nos. 4, 5, 6, 8 and 10 were obtained from Welsh Plant Breeding Station, Aberystwyth ; No. 9 was supplied by the Forest Botanist, Dehra Dun and No. 11 was collected from Kashmir.

It will be seen from the above table that, with the exception of *Bromus patulus* and three species of *Agropyron*, no other grass was infected. This is very significant because these grasses are known to be congenial hosts for one or the other ' Specialized forms ' of *Puccinia graminis* recognised so far [Grove, 1913 ; Stakman and Piemeisel, 1916, 1 and 2 ; Arthur, 1929]. *Bromus patulus* has also been found to be a collateral host of *P. graminis tritici* in this country [Mehta, 1940].

Moderate infection was produced when *Agropyron longearistatum* and *A. semicostatum* were inoculated with uredospores of *P. graminis tritici* and *P. graminis secalis* but only weak infection was obtained with *P. graminis avenae*. On the other hand, none of the three hosts, wheat, rye or oats, got infected with the rust of *Agropyron* as stated before.

The effect of exposure to high temperatures on the viability of fresh uredospores was determined by putting infected leaves in an incubator between 90° and 120° F. The uredo-sori were nearly 7- 9 days old in every exposure. The cut ends of the stalks were dipped in water in specimen tubes whereby the leaves remained quite fresh throughout the period of experiments. Germination was tested in tap water in hanging drops at room temperature (50°—60°F.).

Results show that between 90° and 100° there is no appreciable loss in the viability of the spores in 24 hours. At 100° - 110° and 110°—120°, more than half the number of spores were killed in 18 and 6 hours, respectively, while no germination was noticed in the material exposed for 24 and 12 hours at those temperatures.

6 GENERAL DISCUSSION

From the evidence obtained during the course of these studies, it is clear that the rust found on *Agropyron semicostatum* and *A. longearistatum* in the Simla hills is *Puccinia graminis* Pers., the black stem-rust. Leaves, stems and ears are infected but the attack is heavier on the last two. The uredospores are ovate-oblong, yellowish brown, with four equatorial germ-pores. In size they are smaller than those of *P. graminis tritici*, *P. graminis avenae* and *P. graminis secalis*. There are no mesospores or paraphyses. Teleutospores are bi-celled, very much resembling those of stem rusts of other cereals in appearance and size. Morphologically, therefore, there is little to distinguish the rust under study from the stem rusts of wheat, oats or rye, except in the size of uredospores.

Physiologically, however, the differences are very apparent both in the gametophytic and sporophytic stages of the life cycle of the fungus. These are discussed below in detail.

(i) *Germination of teleutospores*

Teleutospores of the *Agropyron* rust have been found to germinate very well, without undergoing a period of rest, between 40° and 90°F. As recorded by different workers in India and abroad, and also found by the writer, teleutospores of wheat, oats and rye stem-rusts do not germinate outside 45°—70°F. and require a resting period.

It is interesting to note that, whereas teleutospores of wheat stem-rust lose all viability when exposed to high temperatures, those of the rust under reference gave 40 and 20 per cent germination after exposure for 24 hours to 100°—110° and 110°—120° F., respectively.

(ii) *Infection of species of Berberis*

'Specialized forms' of *Puccinia graminis* have been recognised on the basis of their host specialization on the sporophytic side; very little information is available concerning the behaviour of their gametophytes. As stated by Arthur [1929] *Berberis vulgaris* is a favourable host for all except one form hitherto recognised in the sporophytic stage. For the one exception, *viz.*, *P. graminis phlei-pratensis*, a congenial aecidial host is unknown, because, unlike others, *Berberis vulgaris* is not infected at all. Largely for that reason, the rust of *Phleum pratense* has been raised to the rank of a distinct species, *Puccinia phlie-pratensis*.

The *Agropyron* rust differs from other forms of *Puccinia graminis* in its inability to infect *Berberis vulgaris* at all. It has been shown that even young leaves at the age of two days in the case of seedlings did not get infected; there was no evidence of any puncture or injury of the leaf. Unlike *Puccinia phlei-pratensis*, however, several other species of *Berberis* are heavily infected by this rust, resulting in the formation of aecidia. On all these species infection is very much heavier than with the wheat stem-rust and slightly older leaves proved to be susceptible. For this reason, there is no justification in assigning a distinct specific name to this rust. It is quite likely that other forms may behave differently towards various species of *Berberis*, or individual forms as at present recognised by their host range on the sporophytic side, may be further divisible on the basis of their behaviour on different species of *Berberis*.

A parallel case is available in *Puccinia coronata* Corda. Klebahn [1895, 1896] separated it into two species, *P. coronifera* and *P. coronata* chiefly because the former produces aecidia on one group of species of *Rhamnus* while the latter develops aecidia upon another group. Within these two species several forms were recognised on the basis of their specialisation on grass hosts. Other investigators [Arthur and Fromme, 1920; Melhus, Dietz and Willey, 1922], however, prefer to retain all these races as under one species, *P. coronata* Corda, because one species or the other of *Rhamnus* is successfully infected by all of them.

(iii) *The uredo-stage*

Uredospores from pure cultures of this rust have failed to infect Agra local wheat, barley, oats and rye, all of which are heavily susceptible to their respective forms of black rust. Inoculations made on differential hosts of *P. graminis tritici*, *P. graminis avenae* and *P. graminis secalis* gave negative results. Seedlings of *Avena fatua*, *Dactylis glomerata*, *Agrostis alba*, *Poa pratensis*, *Phalaris minor*, *Festuca ovina*, *Panicum Crus-galli* and *Aira flexuosa*, known to be congenial hosts for one or the other specialised form of black rust, also failed to get infected. Successful infection was produced only on *Bromus patulus*, *Agropyron repens*, *A. longearistatum* and A. *semicostatum*.

It is evident, therefore, that the rust under study cannot be placed under any of the known specialized forms of *Puccinia graminis* on the basis of its behaviour in the sporophytic stage also, and accordingly the name *Puccinia graminis agropyri* (Pers.) Mehta and Prasada is suggested for it.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Rai Bahadur Dr. K. C. Mehta, Officer-in-Charge of the scheme for investigation of cereal rusts, for his helpful guidance and the kind interest that he took during the course of these studies. He is very grateful to the Imperial Council of Agricultural Research for the use of greenhouse accommodation and other articles of equipment at the Rust Research Laboratory, Simla. Thanks of the writer are also due to the Director, Welsh Plant Breeding Station, Aberystwyth, and the Forest Botanist, Dehra Dun, for the supply of seed of grasses for these studies.

Summary

The uredo-stage connected with aecidia so commonly found on species of *Berberis* in the Simla hills was discovered during these studies and a complete account of its life-history furnished.

The teleutospores germinate without a resting period between 40° and 90° F. Viability was greatly impaired after exposure to 100°—120° F. for 24 hours and no germination was obtained after 48 hours at 110°—120° F.

Moderate to heavy infection was produced on young leaves of *Berberis lycium*, *B. coriaria*, and *B. aristata*; light to moderate on *B. tinctoria* and light on *B. umbellata*. Only pycnia were produced on *B. pseudumbellata* while *B. vulgaris* Linn. and *B. petiolaris* did not get infected at all.

Inoculations made with aecidiospores produced artificially gave negative results on wheat, barley, oats and rye but uredostage was produced on three species of *Agropyron*, viz. *A. repens*, *A. semicostatum* and *A. longaristatum*.

Aecidiospores found in nature on *B. lycium* and *B. aristata* also infected only the three species of *Agropyron*. Two kinds of aecidia were noticed on *B. coriaria*. *Aecidium montanum* did not infect either the cereals or *Agropyron* but the other type, dealt with in this article, infected only the latter.

In nature leaves, stems and ears of *A. semicostatum* and *A. longearistatum* are found infected with uredo-and teleuto-stages. The uredospores lost their viability after 24 hours' exposure to 100°—110° F. No infection was produced on differential hosts of *Puccinia graminis tritici*, *P. graminis avenae* and *P. graminis secalis*. Seedlings of *Avena fatua*, *Dactylis glomerata*, *Agrostis alba*, *Poa pratensis*, *Phalaris minor*, *Festuca ovina*, *Panicum Crus-galli* and *Aira flexuosa*, known to be congenial hosts for one or the other specialized form of *Puccinia graminis*, also failed to get infected with uredospores of the rust under study. *Bromus patulus*, a collateral host of *Puccinia graminis tritici*, however, got infected.

Cross inoculations made with uredospores of *Puccinia graminis tritici* and *P. graminis secalis* resulted in moderate infection of the three species of *Agropyron*, while *P. graminis avenae* produced weak infection.

Results are discussed in detail to show that the rust is a new specialized form of *P. graminis* and the name *P. graminis agropyri* (Pers.) Mehta and Prasada is suggested.

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FIELD EXPERIMENTS ON RECLAMATION OF SALT LANDS IN BARAMATI OF BOMBAY DECCAN*

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(Received for publication on 5 March 1946)

(With plates IX—XI and six text-figures)

AMONGST the soil conditions affecting plant growth, the supply of plant nutrients and various other factors play a very important part.

It is well known that alkali soils are very sticky when wet and are impervious to water, and on drying form hard cakes at the surface. The intensity of these properties depends upon the quantity and conditions of colloids. It is, therefore, very essential to restore these soils to their normal conditions for plant growth in the initial stage of reclamation. This means that the soil has got to be brought to its original crumbly state or that the soil must be brought to good tilth. This can be achieved by deep tillage and addition of chemical fertilizers in combination with organic manures.

It is also observed that the soils, which are partially reclaimed, require careful tillage in the beginning as *vapsa* (optimum moisture) conditions remain for a temporarily short period than in the case of normal soils, specially during the wet season.

Another important point is the loss of organic matter usually occurring in alkali soils on leaching. Greaves [1927] in this connection has pointed out that 'Organic manures were essential for the restoration of alkali soils to a high state of productivity'. Thus after securing the necessary good tilth the next step to follow is the selection of crops resistent to alkaline or saline conditions.

Henderson [1920] in his note on practical salt land reclamation mentions about the rice crop as resistent to alkali salts. Similarly Mann and Tamhane [1910] suggest growing of salt rice from Konkan during the process of reclamation. They also recommend growing of *wal* (*dolicus lablab*) *chawali* (*Vigna catiang*) and Ambadi (*Babiscus cannabinus*). Puri [1935] has also worked out relationship between degree of alkalization and crop yield in the Punjab.

The work done at Baramati described in this paper is in connection with the study of lands affected with salt deposits with high subsoil water for years. Subsoil drainage reduced the high water table and made reclamation possible. The process of leaching out salts, the growing of successful crops, in the initial stages of reclamation according to the degree of salinization, and the stand of crops with progress of reclamation has been described. Basu and Tagare (1943) have described work at Padegaon in connection with (natural) alkali soil, called *chopan* with deep water table. It mainly deals with the nature of alkali soils and the various soils tests before and after crop growing.

In a reclamation process, therefore, every worker finds it quite essential to select crops which are resistent to salinity or alkalinity in the initial stage of reclamation.

Experimental technique

Laboratory and Field methods were the same as described in previous papers [Talati, 1941–1942].

Fig. 1 gives the area wherein all the experiments described in this paper were conducted. This area known as the Baramati Experimental salt area was one of the worst salt affected area under Deccan Canals. The subsoil water table was very high which ranged from ground level to 1–2 ft. from the surface while the solube salts varied from 2·5 to 4 per cent or even more. The whole area was underdrained by putting in pipe lines and open drains described in details by Inglis and Gokhale [1928] and attempts were then made at reclamation after reduction in the subsoil water table.

* This paper is in continuation of the paper published in *Indian Journal of Agricultural Science* (XI, VI) December 1941.

FIG. 1a. Experimental salt land Baramati. Nira Left Bank Canal
Scale 1 in. = 1,100 ft.

The description of the profiles affected with salts was as given in Table I.

TABLE I

Description of the profiles affected with salts.

Mixed saline soils				Saline soils	
I		II		III	
0—6 in.	Fine black, loose and granular	0—12 in.	Loose red soils	0—12 in.	Grey black structureless
6—12 in. and 12—24 in.	Black Soil compact fissured	12—24 in.	Slightly stiff minute crystal, of gypsum	12—36 in.	Clody grey black structure containing laminated lime
24—36 in.	Greyish stiff		.....		....
36—72 in.	Yellowish clay large, prismoidal structure pieces, gypsum crystals	24—60 in.	Prismoidal red clay with gypsum crystals or lime *kanker*	36—48 in.	Fissured *chopan*
72—84 in.	Massive *kanker*, fine sandy material easily breaking into powder (locally known as *mān*)		.....	48—60 in.	Yellowish prismoidal clay

The types of profiles described in Table I were leached to a stage in which crops could be established. For detailed description of the profiles for noting calcium-sodium concentration and other characteristics, the previous publication on this subject by Talati [1941] may be referred to.

Reclamation of mixed saline soils (consisting of mixed salts of calcium and sodium)

Leaching under field conditions.

A typically salt affected patch of about six acres was provided with adequate drainage. After the subsoil water was lowered to more than four feet from ground level, this area was ploughed up, levelled and divided into small plots of one *guntha* each according to the slope of the ground. Fig. 1b. will explain the layout more clearly.

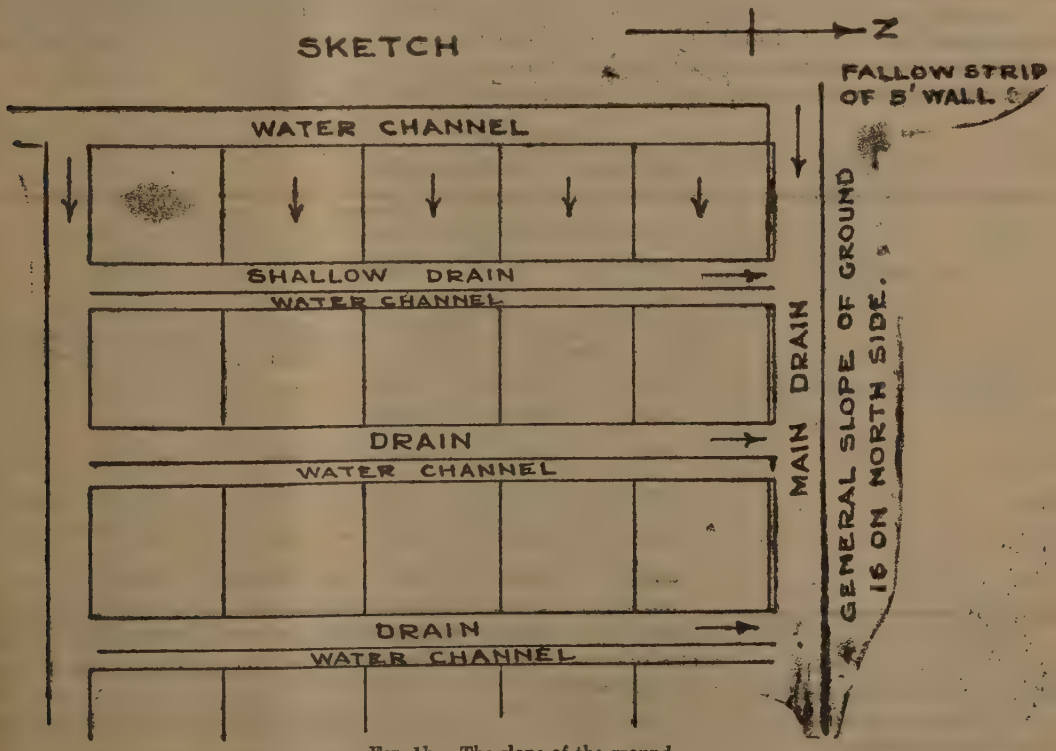

FIG. 1b. The slope of the ground

These plots were continuously under water for four months during monsoon from July to October and received about 160 acre inches of water. It was observed that about 25 in. of water evaporated (based on evaporimeter readings--Open Pan Evaporimeter, Indian type) leaving about 135 in. of water which drained through the entire soil profile, part going into subsoil drainage and part into the shallow gutters joining the main open drain.

Soil samples were collected at three typical spots before leaching ; samples were also similarly collected after leaching. The results are set out in Table II.

TABLE II

Salt content of soil samples before and after leaching

Soil depth	Description of profile	Profile No. 1		Profile No. 2		Profile No. 3	
		Total salt percentage					
		Leaching		Leaching		Leaching	
		Before	After	Before	After	Before	After
0—6 in.	Salty black soil	2·65	1·00	3·00	1·025	3·50	0·925
6 in.—1 ft.	Ditto.	2·10	1·20	2·85	1·27	2·85	0·737
1—2 ft.	Yellow coloured loose soil	2·50	1·00	3·00	1·12	3·00	0·825
2—3 ft.	Ditto.	3·25	1·10	1 75	1·25	2·75	0·700
3—4 ft.	Fissured loose clay brownish	2·40	1·025	3·00	...	3·25	0·492

The results in Table II show good effects of leaching. The total soluble salts considerably leached out from about 3 per cent to less than 1 per cent. The reduction is, however, not uniform in all profiles which may be due to the nearness or otherwise of the main drain.

The *p*H values of the leached profiles were as shown in Table III.

TABLE III

The pH values of leached profiles

Soil depth	*p*H values					
	Profile No. 1		Profile No. 2		Profile No. 3	
	Before leaching	After leaching	Before leaching	After leaching	Before leaching	After leaching
0—6 in.	8·46	8·06	7·84	7·72	8·02	7·44
6 in.—1 ft.	8·78	8·28	8·54	8·94	8·14	8·28
1—2 ft.	8·92	9·22	7·82	9·16	8·00	8·17
2—3 ft.	8·74	9·80	8·32	9·06	8·34	8·24
3—4 ft.	8·46	9·46	8·00	9·78	7·14	8·02

The results given in Table II show that *p*H values were appreciably reduced in the top six inches with an appreciable increase in lower horizons. This was because on leaching, sodium was hydrolised in lower horizons and this produced alkalinity.

The humus contents of these before and after leaching were estimated and the results given in Table IV were obtained.

TABLE IV

Humus contents before and after leaching

Soil depth	Humus percentage	
	Before leaching	After leaching
0—6 in.	0·3107	0·3346
6in. —1 ft.	0·3824	0·2868
1—2 ft.	0·4302	0·2868
2—3ft.	0·3585	0·2748
3—4 ft.	0·2987	0·2748

It will be seen that except for the top 6 in. there was considerable depletion of humus from 6 in. onwards.

Next year during monsoon, a crop of *dhaincha* (*Sesbania aculeata*), a robust green manuring crop, was tried. The stand of the crop was quite good. After the crop was removed, the soils were again examined for soluble salts, *p*H values and humus contents with results as indicated in Table V.

TABLE V

Soluble salt contents, pH values and humus percentage of soil

Soil depth	Percentage of total soluble salts	*p*H Values	Percentage of humus	Percentage of humus in normal soils of the same type nearby	Remarks
0—6 in.	0·30	8·04	0·32	0·82	Salts were found out from oven dry soils
6 in.—1 ft.	0·32	8·32	0·33	0·70	
1—2 ft.	0·27	9·08	0·37	0·52	
2—3 ft.	0·24	9·45	0·32	0·32	
3—4 ft.	0·62	9·24	0·28	...	

These results show that leached soils are deficient in humus as compared to normal soils of the type and hence it is essential to add bulky manures to enrich them and also to restore their tilth to normal conditions.

Saline soils of C type (alkali soils) had to be leached for three seasons to reduce excessive salts. The total inch-depth of irrigation applied for leaching in all the three seasons was about 275 acre inches which included evaporation amounting to 95 in. At the end soluble salts, *p*H values capillary rise and humus contents were noted ; the results are given in Table VI.

TABLE VI

Results of leaching of alkaline soils

Soil depth	Percentage of soluble salts	*p*H values	Percentage of humus	Percentage of humus in normal soils nearby	Remarks
0—6 in.	0·43	9·72	0·12	0·82	
6 in.—1 ft.	0·52	10·01	0·15	0·70	
1—2 ft.	0·28	9·85	0·04	0·52	The capillary rise observed for 300 minutes did not show any rise in any of these samples.
2—3 ft.	0·33	10·08	0·32	0·32	
3—4 ft.	0·22	9·87	0·36	...	

The results given in Table VI show that leaching reduced soluble salt contents but increased the *p*H values to an appreciable extent. The humus contents were considerably reduced in leached soils. Thus these C type of alkali soils on leaching get strongly alkaline which require chemical treatments for their improvement which are described later.

Role of local sugarcane (Pundia) in reclamation

Field observations were made after the crop had established itself in the field. Observations were taken at each graded growth, and demarcations were carefully made where there was a uniformly good crop in several rows followed by appreciable change from good to medium and further on to patches with inferior growth. This will be clear from Plate IX, figs. 1 and 2 taken in a graded growth of sugarcane plot.

This was done in the same soil type (deep soil) as near as possible and under identical conditions of preparatory tillage, manuring, irrigation and after care. Soil samples were taken from the first foot pounded in wooden mortar, passed through 1 m.m. sieve and used for experimental tests.

The following tests were carried out :

(1) Capillary rise in five hours.

(2) *p*H values.

(3) Salt content by Dionic Water Tester.

The idea in carrying out these tests was to note which factor had a dominant effect on the growth of crops.

Study of sugarcane

The cultivators on Deccan canals grow Sugarcane known as Pundia, which is a thick cane, fairly rich in sucrose and is a good yielder, but the main drawback is its sensitivity to even slight salinity or alkalinity. Before other varieties were introduced, this was exclusively planted by cultivators as it is a very soft cane and can be crushed with bullock crushers. Evidently one had to wait for a long time after drainage to make soil conditions ideal for growing successful crops. The study of the resistance of this local cane was made in the Experimental Salt Area. Nearly 250 representative soil samples one or more from each plot was taken from the surface 12 in. depth, because it was noticed that the roots at this stage of the crop penetrated almost to 12 in. depth, in the soil. Plate IX, fig. 3 illustrates the root system taken from good and inferior growths of sugarcane of Pundia and CO 290 varieties.

After getting the samples of the required type, soil extracts were prepared and *p*H values were found out by the colorimetric method (Clark and Lubs) using 1 to 10 soil water ratio. The total soluble salts were also found out by the Dionic Water Tester and capillary rise was noted for five hours. The results showed a variation in *p*H values ranging from 7·3 to 9·0 with varying capillary rise and salt contents. Table VII gives the mean results of each grouping.

FIG. 1. Graded growth of sugarcane in mixed Saline soils

FIG. 2. Graded growth of sugarcane in strong alkali soils

FIG. 3. Root system of sugarcane in alkali soils. (1) Co. 290, good root system ; (2) Co. 290, inferior root system ; (3) Pundia, good root system (4) Pundia, inferior root system

TABLE VII

Average pH values and capillary rise and soluble salts of soil samples

Serial No.	pH values	Capillary rise in cm.	Percentage of soluble salts by conductivity	Remarks
1	7·30	14·00	0·33	Average of 3 tests
2	7·4	14·70	0·29	,, 3 ,,
3	7·5	12·95	0·25	,, 12 ,,
4	7·6	11·70	0·31	,, 16 ,,
5	7·7	13·30	0·34	,, 3 ,,
6	7·8	13·75	0·27	,, 30 ,,
7	7·9	13·80	0·25	,, 3 ,,
8	8·0	12·40	0·25	,, 25 ,,
9	8·1	13·55	0·25	,, 16 ,,
10	8·2	14·20	0·30	,, 38 ,,
11	8·3	12·40	0·36	,, 16 ,,
12	8·4	8·50	0·30	,, 22 ,,
13	8·5	6·60	0·45	,, 8 ,,
14	8·6	7·20	0·32	,, 14 ,,
15	8·7	2·50	0·37	,, 12 ,,
16	8·8	2·20	0·42	,, 11 ,,
17	8·9	0·70	0·46	,, 4 ,,
18	9·0	0·00	0·38	,, 16 ,,
				Total 242 tests

The results given in Table VII are reproduced in Fig. 2. The figure clearly shows the close relation between *p*H values and physical conditions of the soil. The soil tilth is very good as indicated by the capillary rise varying from about 7·0 140 cm. and as indicated by *p*H up to the value of 8·6 beyond which it is bad being *nil* at *p*H 9·0.

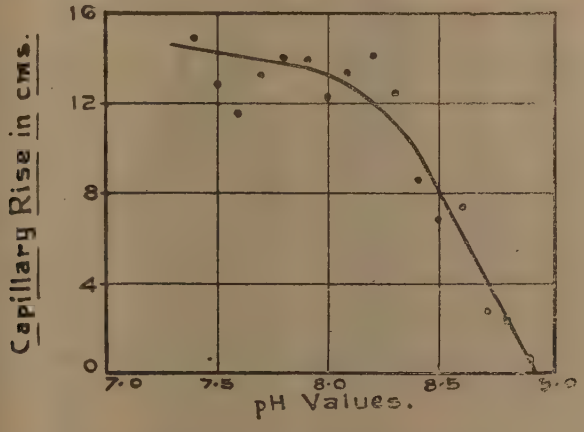

FIG. 2. Capillary rise and *p*H values of plots of Baramati Experimental Salt Area

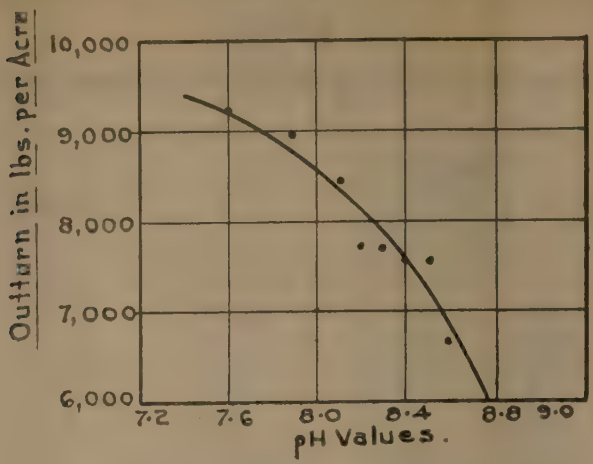

FIG. 3. Outturn of *pundia* cane in various plots of Baramati Experimental Salt Area with varying *p*H values

Fig. 3 shows the outturn and the average *p*H values of several plots in the Experimental Salt Area where Pundia Sugarcane was grown. It shows a marked reduction in outturn with increasing *p*H values, it being somewhere near 30 *pallas* (*7,500* lbs. of gul.) at 8·4 *p*H. This confirms observations of Fig. 2.

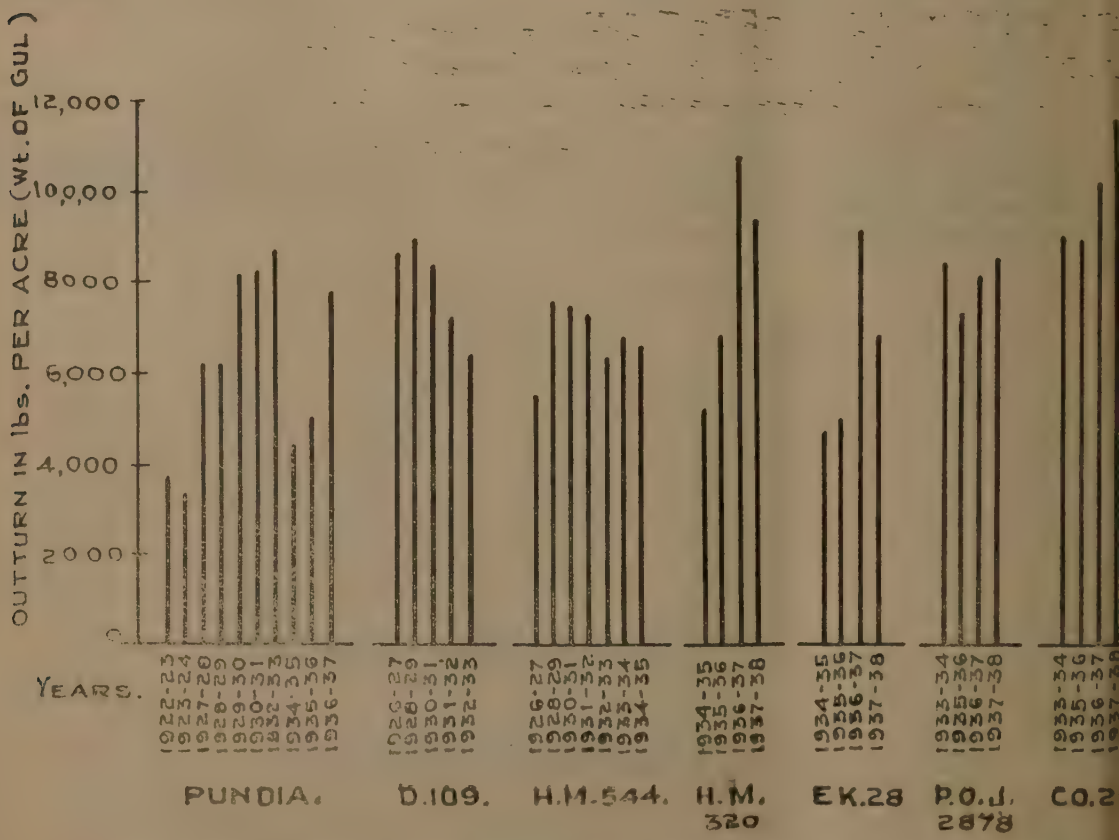

FIG. 4. Outtern of different varieties of sugarcane in Experimental Salt Area Baramati in different years.

Reclamation experiments with sugarcane varieties

Up to 1925-26 Pundia alone (a local cane) was grown in salt lands. Since 1926-27 several varieties of cane newly introduced into the canal tracts have been under test as regards their resistance to salts and sodiumisation, but little progress was made until 1932-33. Of the varieties tried only D 109 and HM 544 continued to give yields nearly as good as Pundia. But even these were noticed to deteriorate in course of time. D 109 showed tendency to lodge and put up crocked canes troublesome to crush. HM 544 produced inferior gul. The varieties as a rule did not then tiller well and germination was affected by the impervious soil which did not dry up soon. Dry plantation and light watering had, therefore, to be resorted to in some cases. Cane was rotated with robust fodder crops such as *nilwa, jowar and dhaincha* (*Sesbania aculeata*) to provide green manure previous to the planting of cane. Cotton was selected to grow after cane as it yielded well and improved the soil. The early cane varieties tried received bulky manures at the rate of 10,000 lb. per acre and in addition a dose of 150 lb. of nitrogen was given as top dressings in form of ammonium sulphate and oil cakes.

POJ 2878 and HM 320 succeeded well and gave much higher return than Pundia. After 1932-33, CO 290 variety was intoduced. This was found to be very resistant to salt (1 to 1·5 per cent salts) and sodiumised soil with *p*H 9·96. POJ 2878 stood next in tolerance to alkalinity. It stood up to 9·7 *p*H, but not salts exceeding 0·5 per cent. POJ 2883 and EK 28 were comparatively very sensitive.

The performance of different varieties tried in salt lands from 1922-23 to 1932-33, will be clear by reference to Fig. 4, which gives outturn year after year. The results indicate how certain varieties deteriorated in course of time while others not only maintained their yields but gave increasing yields.

The system of randomisation and replications which being capable of statistical treatment gives decisive results was introduced since 1933-34. The results are summarised in Table VIII.

TABLE VIII

Results of varietal trials

Serial No.	Description	Pundia	HM320	EK 28	POJ 2883	POJ 2878	CO 290	Significance figure
1	Alkaline soil *p*H 9·2 (lower -area), 1934-35	11·01	14·13	18·99	24·28	25·99	Not tried	9·98
2	Mixed Saline soils (lower area) *p*H 8·5 to 9·0·6 replicates 1935-36	20·88	36·36	23·00	35·65	36·97	51·88	9·16
3	Middle area, mixed saline soils 6 Replicates, 1935-36	32·36	34·70	29·08	34·84	35·38	54·41	8·32
4	Lower area 1936-37, 5 replicates	38·83	48·90	46·84	47·44	48·34	71·73	16·04
5	Middle area, 6 replicates, 1936-37	25·45	38·07	35·35	35·05	27·57	51·41	10·36
6	Lower area, 1937-38 . .	22·78	38·41	37·93	37·16	47·30	56·99	10·16
7	Middle area, alkali soil, 1937-38	11·73	25·94	20·04	19·77	24·00	40·13	8·25

The results show that CO 290 has given highly significant results all through. POJ 2878, HM 320 and POJ 2883 have given in four out of seven cases examined.

During 1938-39, several new varieties were tried in alkali soil (C type) of the description as given in Table IX.

TABLE IX

Depth of soil	*p*H values by electrical method	Capillary rise in 5 hours		Percentage of soluble salts
		Distilled water	Normal NaCl solution	
0—6 in.	9·92	0·50	1·60	0·19
6—12 in.	9·88	0·50	1·70	0·20
1—2 ft.	9·72	0·55	1·30	0·32
3—4 ft.	9·00	0·65	2·90	0·24
6—7 ft.	8·80	2·70	4·05	0·23

The results as given in Table IX show that though the soluble salts were low, the soil was highly alkaline. Cane was planted on 5 January, 1938. Partial earthing up was done in July, while complete earthing up was given by the middle of August. After these operations, the growth in the case of CO 290 and CO 419 made good progress.

The outturn of different varieties are tabulated in Table X.

TABLE X

Results of outturns (converted into *pallas*. 240 lb. = 1 *palla*.)

Cane variety	Outturn in *pallas* per acre				Total	Mean
	Blocks					
	1	2	3	4		
CO 360	27·4	33·3	21·5	26·0	108·2	27·0
CO 419	56·8	45·0	18·5	30·5	150·8	37·7
CO 408	37·3	27·2	18·6	25·7	108·8	27·2
CO 290	39·6	45·2	39·4	37·0	161·2	40·3
CO 417	33·3	29·7	29·1	37·4	129·5	32·4
POJ 2878	22·5	22·7	11·7	19·2	76·1	19·0
TOTAL	216·9	203·1	138·8	175·8	734·6	..
MEAN	36·0	33·8	23·1	29·3	G.M.	30·6

Significance figure 9·95

From the data as indicated in Table X it will be seen that CO 290, CO 419 and CO 417 are significantly better than POJ 2878 : CO 290 stands out the best followed by CO 419.

During 1940-41, the experiment was continued in highly alkaline soil of the description as given in Table XI.

TABLE XI

Soil tests of C2 type under experimentation

Soil depth	Replaceable Na+K X-Milliequivalent percentage	Replaceable Mg.	Replaceable calcium	Total bases	pH values		Percentage of soluble salt	Ratio of Replaceable Ca to Na and K
					In Water	In N-KCl solution		
0—6 in.	13·196	7·54	18·36	38·568	10·02	7·56	0.950	1·39
6—12 in.	15·228	8·44	7·14	30·81	10·12	8·82	1·200	0·47
18—24 in.	0·048	9·82	17·34	33·208	10·28	7·82	0·600	2·87
24—36 in.	13·068	12·88	10·71	36·658	10·54	8·32	0·900	0·82

The preparatory tillage was given by means of Gallows Plough. Two ploughings were given. The land was divided into deep ridges and furrows by a heavy ridger. The area was then divided into small sub-plots of one *guntha* and alround shallow drains were opened out. These shallow gutters were joined to main drains. Farmyard manure was spread in the furrows at the rate of 15,000 lb. A basal dose of three tons of gypsum was also given at this stage and spread in furrows. The soil was then thoroughly stirred with pickaxes. On this a layer of *pachat* was spread at the rate of 10 tons per acre. The V-shaped furrow thus turned into a flat shape. *Dhaincha* was lightly broadcast at the rate of 30 lb. per acre. Dry planting was resorted to during August 1940. Seed rate was increased to 12,000 setts per acre and light irrigation was given. Due to light showers good germination was secured. *Dhaincha* was burried in again with *kudali* (pickaxes) after two months by taking little soil from the ridge portion.

After 3½ months the *pachat* layer was completely rotted and it added organic manure to the soil. Partial earthing up was given after five months and complete earthing up was given when the canes developed three internodes. Very light irrigation was given throughout ; 225 lb. of Nitrogen was given by the time of earthing. This was the first successful crop in such highly alkaline soil.

Result of cane outturns in saline alkali (highly alkali) soils

Date of plantation : 20 August 1940 } Adasali cane.
Date of Harvest : 10 January 1942 }

TABLE XII

Cane outturns in highly alkali soils

Name of variety	Outturns of cane in tons per acre	Difference from CO 419	Brix of juice	Percentage of sucrose	Remarks
CO 419	35·88	*Nil*	20·70	15·89	The Experiment was conducted with 5 replicates
CO 417	54·93	19·05	20·14	16·61	
CO 411	44·52	8·64	20·82	16·44	
CO 426	48·45	12·57	17·82	14·04	

Significance figure 15·06

Out of CO varieties CO 417 gives significantly greater yield than CO 419 variety. CO 426 is a runner up. CO 417 is a promising cane for saline alkali soils, while CO 419 variety, which gives good results in alkali soils up to 9·5 *p*H, gave poor results in strong alkali soils. Plate X, figures 1 and 2 shows the growth of different cane varieties after maturity.

Bulky manure experiment in mixed saline soils

As stated above early experiments were laid out with local cane Pundia which was a favourite cane with the cultivators.

The Experiments were continued in four blocks serving as replicates with the following treatments randomised in each block.

(1) 10,000 lb. of Farmyard manure
(2) 20,000 ,, ,, ,,
(3) 30,000 ,, ,, ,,
(4) 40,000 ,, ,, ,,
(5) 50,000 ,, ,, ,,

There were 20 subplots measuring two *gunthas* each with a ring alround. The *p*H values of these plots were from 8·5 to 9·0 (B type), while average salt contents were 0·5 per cent. As stated above the local cane Pundia was tried from 1933 to 1935 and the tolerance study carried out by the writer thereafter threw much light on the crop growth and other varieties were immediately introduced.

Planting was done on sides of furrows and with hands (instead of pressing with legs) to keep them in the first two inches only so as to protect the eyebuds from excessive moisture in the initial stages. This method secured good and uniform germination. Artificial top dressing was given in addition to farmyard manure. The artificial manure was given as under :

Time	Manure	Dose
First dose 1½ months after planting	Ammonium sulphate and groundnut Cake.	25 lb. per acre 25 ,, ,, ,,
Second dose 2 months ,, ,,	Ammonium sulphate	25 ,, ,, ,,
Third dose 4 months ,, ,,	Groundnut cake	25 ,, ,, ,,
Fourth dose 6 to 7 months ,, ,,	Castor Cake	50 ,, ,, ,,

About six weedings were given, while 36 irrigations were given in all. Partial earthing up and full earthing up were given after four months and 6½ to 7 months of planting. The most important point in irrigation was to give slow irrigation and see that there was thorough soaking of the soil and no free water was allowed to be kept in the furrows. The quantity of water given in such soils was 100 acre inches.

The results of outturns are given in Table XIII.

TABLE XIII

The results of bulky manure experiments

Serial No.	Description	Treatments					Significance figure.
		10 carts 10,000 lb	20 carts	30 carts	40 carts	50 carts	
1	Lower area *p*H 8·10 (Pundia 1933-34)	38·44	59·03	54·35	69·42	79·09	12·42
2	Middle area *p*H 8·0 (Pundia 1934-35)	20·67	37·46	40·20	45·57	51·28	6·96
3	Middle area *p*H 8·5 (Pundia 1934-35)	22·87	27·97	36·60	38·54	26·63	4·57
4	Lower area *p*H 9·0 (POJ 2878, sugarcane variety 1935-36)	30·23	36·09	44·72	38·86	41·71	13·20
5	Middle area *p*H 9·0 (variety 2878 1936-37)	32·80	38·66	41·47	35·83	30·41	19·5

FIG. 1. Bumper crop of CO 290 variety of sugarcane after reclamation

FIG. 2. Stand of different CO varieties as *adsali* crop in strong alkali soil. Left to right (1) CO 426, (2) CO 411, (3) CO 419, (4) CO 417

FIG. 1. Normal crop of *shalu jowar* crop two years after various treatments

FIG. 2. A bumper crop of *dhaincha* green manure in upper Area of Baramati after leaching

On referring to Table XIII, it will be seen that treatment variation was significant only in two cases where the soil was of mixed saline type with *p*H 8·5 to 9·0. In the rest of the cases the treatment variation was not significant as the soil was of C_1 type and farmyard manure alone failed to cause any response.

The results on the whole, whether statistically significant or not are very instructive and, after consideration of all cases lead to the conclusion that farmyard manure appears to have slightly increasing effects with 10 to 30 carts.

Subsequent doses of 40 to 50 cartloads increased the outturn in good soil plots but reduced it in stiff soil plots, due to want of proper aeration necessary for humification. The results on the whole show that in stiff alkali soil (*p*H about 9·0), farmyard manure alone is not significantly effective. Farmyard manure may be used to a maximum quantity of 30 cartloads per acre as may be justifiable economically but it is wasteful to use farmyard manure in excess of this quantity.

During 1938-39, CO 290 variety was planted on 15 March 1938 and irrigations were given as usual. Treatment besides farmyard manure was given to see the relative efficacy of each of the bulky manures.

Treatment	*Dose per acre*
(1) **Farmyard manure**	30,000 lb.
(2) **Sheep manure**	15,000 lb.
(3) **Blank or no treatment**	

There were 20 subplots, measuring two *gunthas* each. The *p*H values of these plots were on an average above 8·5 while the salt contents were 1·1 per cent.

The results of outturn were as under given in Table XIV.

TABLE XIV

The relative efficacy of bulky manures

Treatment	Block 1	Block 2	Block 3	Block 4	Mean
Blank or no treatment	37·5	34·2	31·4	38·2	35·3
Sheep manure	41·2	40·6	35·3	41·0	39·5
Farmyard manure	40·7	46·3	41·4	48·0	44·1
Mean	39·8	40·4	36·0	42·0	G.M.
Significant figure	3·41	..	..	..	39·6

The results show that farmyard manure stands first in the experiment.

Experiments with chemical fertilizers

In slightly still stiffer soils experiments were laid out with different doses of gypsum varying from 1 to 3 tons per acre. CO 290 variety of sugarcane was tried. The method of planting, weeding, and irrigation was just the same as described in the previous sugarcane experiments with bulky manures. Gypsum was applied in furrows along with farmyard manure.

For statistical treatment yields of cane in tons per acre were taken into account in all cases as this excluded errors due to crushing, etc. The subplots were of $3\frac{1}{2}$ *gunthas*, size excluding ring of $1\frac{1}{2}$ *gunthas*, the net experimental subplot was 2 *gunthas*. The experiments with doses of gypsum from 1 to 3 tons per acre were laid out in randomised treatments in replicated plots. The results were examined statistically. The area being under reclamation soil variation was rapid and so random errors due to soil difference were high. Still five experiments out of eight gave significant results. These are summarised in Table XV.

TABLE XV

Yield of sugarcane with varying doses of gypsum and other fertilizers

Treatments	Old series					Treatment per acre in addition to basal dose of farmyard manure	New series			Remarks
	1933-34	1933-34	1934-35	1934-35	1934-35		CO 419 variety of sugarcane			
	Lower area, plot Nos. 18, 23, 24 (CO 290 variety)	Lower area plot Nos. 19 and 19A (Pundia)	Lower area, plot Nos. 27, 28 (CO 290 variety)	Lower area, plots 5, (a), 6, 7 (CO 290 variety)	Middle area, plots 84 to 86, 88 and 89 (CO290 variety)		1938-39	1939-40	1 40-41	
Per acre	(20 cart loads) farmyard manure	(10 cart loads) farmyard manure	(20 cart loads) farmyard manure	(10 cart loads) farmyard manure	(10 carts) farmyard manure					
	Mean yields per acre (tons of canes)						Mean yield per acre in tons			
Blank	30·45	31·95	24·74	21·66	23·46	Blank	30·70	46·70	44·80	In new series, doses were fixed on basis of equal cost
One ton gypsum	44·90	39·26	27·99	30·87	28·16	Gypsum (8,400 lb).	38·8	51·90	57·9	
2 tons gypsum	48·56	44·45	29·80	37·77	34·55	Calcium carbonate (crushed 8,400 lb.)	35·7	38·30	40·0	
3 tons gypsum	51·28	52·33	33·35	44·97	48·85	Sulphur (¼ ton)	33·9	47·80	48·8	
Significance figure	3·50	7·12	4·52	7·94	10·62	....	..	..	..	

It is seen from Table XV that the outturn of cane increased with the doses of gypsum and that the yields from 2 to 3 tons treatments were always significant as compared to 'No Treatment'.

The outturn during the years 1938-39 to 1940-41, with other treatments besides gypsum show that gypsum and sulphur gave alternately good results.

Soil Improvement in presence of rotational crops (Seasonal)

Research in the laboratory and small plot experiments had shown that stiffness of the soils in the Experimental Salt Lands at Baramati on the Nira Left Bank Canal was due to the presence of sodium clay and for the recovery of soil tilth it was necessary to convert sodium clay into calcium clay by base replacement. Farmyard manure alone, though very essential, was not of much use in this respect. Several cane varieties, bulky and chemical manures were tried on a large scale in stiff soil plots in presence of sugarcane crop to determine the dose adequate for such soils. This experiment was conducted in presence of seasonal crops to see the effect of intermittent irrigation on the alkali soil.

Experiments

Several soil improvers as detailed below were applied in plots 5b and 5c in the salt lands where the soil was very stiff and no crop could grow hitherto. The following analytical data clearly show the nature of the soil in 1937 :

Serial No.	Test	Percentage	Remarks
1	Total soluble salts	0·47	Alkali soil of C_1 type
2	*p*H value	9·16	
3	Capillary rise in distilled water in five hours	2·50 cm.	
4	Capillary rise in N Nacl solution	17·00 ,,	

The improvers were either used singly or in combination in small plots of $16\frac{1}{2}$ ft. $\times$ $16\frac{1}{2}$ ft.

The whole experiment was subdivided into four sub-experiments, *viz.* :

1. Use of calcium salts, *viz.* :
   (1) Calcium carbonate
   (2) Calcium sulphate (local produce 86 per cent purity)
   (3) Calcium carbonate
2. Use of sulphur and sheep manure used singly
3. Use of sulphur in combination with calcium salts, and farmyard manure
4. Use of sheep manure in combination with calcium salts and sulphur
5. Use of all improvers such as :
   (1) Sheep manure
   (2) Farmyard Manure
   (3) Compost
   (4) Calcium sulphate
   (5) Oil cake
   (6) Molasses

Experiment III

Calcium sulphate + sheep manure was the best treatment for both the years.

Experiment IV

Sheep manure stood first for both the years. The results obtained with farmyard manure are only slightly lower than those with sheep manure.

To summarise, the results are on the whole much in favour of calcium sulphate as hitherto. Slight effect of sulphur with time was seen in Experiment I, but in Experiment II considerable lowering of the yield was observed.

In the case of Molasses an increase in yield was seen one year after the addition. Sheep manure although promising can be replaced by farmyard manure when the former is not available.

Trial of Rotational Crops during and after reclamation

It is seen that sugarcane is the principal crop in the Deccan Canals and is remunerative both to the cultivators and the state. Hence after studying the different suitable varieties the next important item to study was the suitable rotational crops to sugarcane. Different rotational crops of this locality are :

Serial No.	Name of crop	Kind of crop	Time of sowing
1	*Nilwa jowar*	Fodder crop, seasonal crop of four months	Monsoon ; June
2	*Shalu jowar*	Fodder crop of four months . . .	15 September
3	Cotton	Fibre crop of four months . . .	15 April

Tolerance of some of these crops was studied in detail by taking a number of soil samples up to 12 in depth at each graded growth of crop, *p*H values (electrometric), soluble salts and capillary rise were found out for soils at each graded growth. The results are interesting and are set out in Fig. 5. From this it will be seen that the order of tolerance of these crops is as under :

(1) *Nilwa*, (2) Cotton and *shalu*

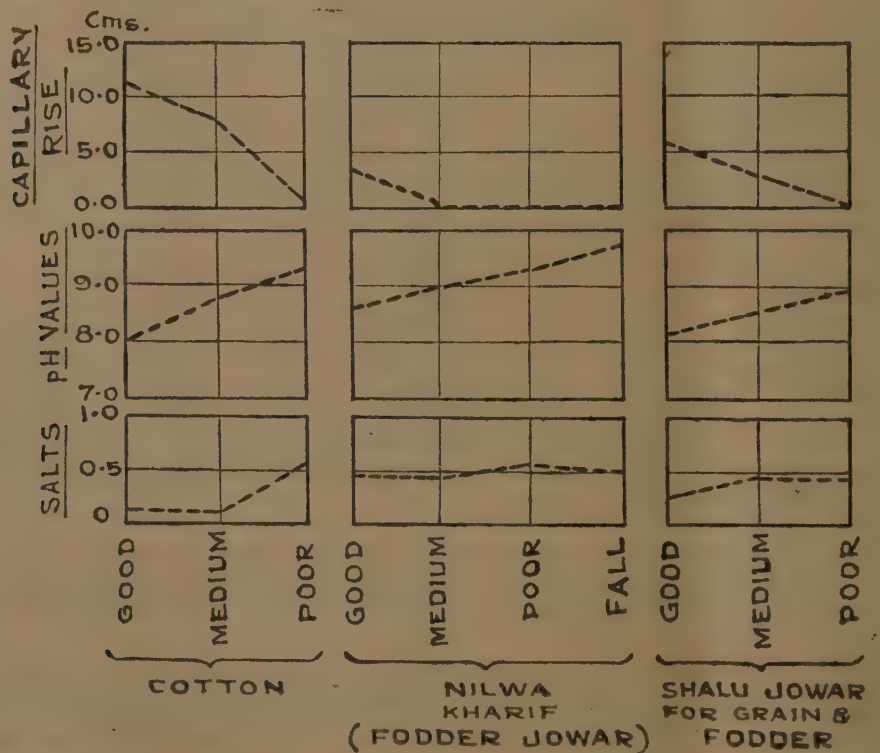

Fig. 5. The relative resistance of various crops to saline or alkaline conditions

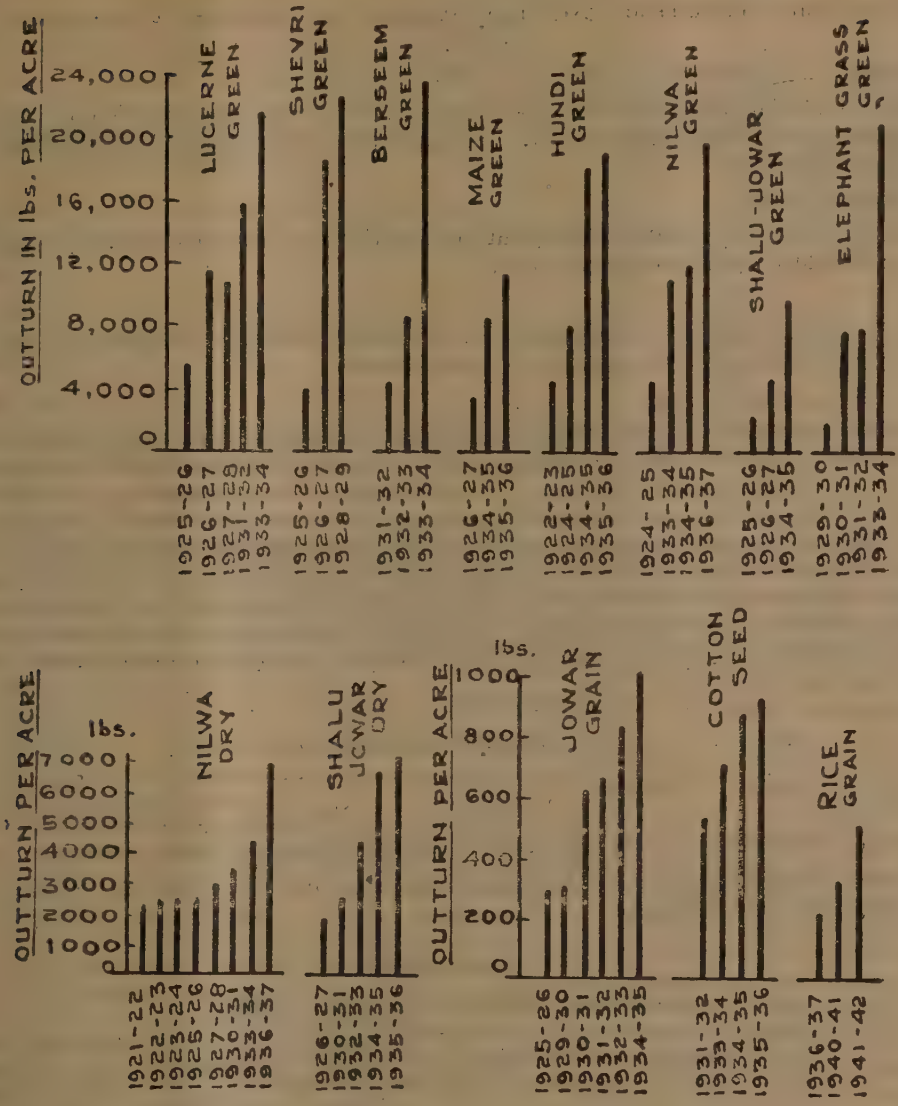

Fig. 6. Outturn of fodder, grain and other crops in Baramati Experimental Salt Area during different years

Sowing of fodder crops was done by one shallow ploughing followed by harrowing. Higher seed rate was used as a rule ; 25 per cent more seed rate gave good results. Cotton was dibbled after harvesting of sugarcane without any preparation. This crop improved the soil by its deep root system and gave a fairly good yield on account of the residual effect of previous manure given to sugarcane crop.

The results of different fodder crops year after year are summarised in Fig. 5 which shows that increasing yields were obtained year after year, indicating the progress of reclamation. The results show the part played by rotational crops in the process of reclamation.

Amongst other perennial crops tried, *shevari* gave promising and quick results. This is the most tolerant of all crops tried so far and resists salt up to 1 to 1·5 per cent and can grow well in soil up to 9·5 to 10·0 *p*H. Lucerne comes next to it.

The comparative outturns are given in the statement and conforms the statement of its tolerance.

Berseem fodder

This is a valuable fodder and gives good outturns. The crop grows in soils up to *p*H value of 9·5 but it fails with further increase of *p*H. It is however, sensitive to salt and it suffered badly at 0·50 per cent salt contents.

Maize and hundi fodder

These are also very valuable fodders but are sensitive and are recommended for trial in soils where *nilwa* (fodder *jowar*) thrives very well.

Paddy

This is a useful crop for mixed saline soils. It thrives well up to 0·62 per cent salts and *p*H up to 9·0 ; with higher salts, the growth is at once checked.

Trial of green manuring crops

The most improtant rotational cropping in sugarcane plantation is trial of green manures. Sunn green manures (*Croltalaria juncea*) is common on the Deccan Canals and grows luxuriantly. A very good crop weighs 30,000 lb. per acre. Its main drawback is its sensitivity to a little salinity or alkalinity. It is also frequently attacked by wilt and leaf diseases particularly in heavy deep soils. This was. therefore replaced by another green manuring plant *Sesbania aculeata*, locally known as *dhaincha*. It is a hardy plant with green feathery leaves with pale yellow pea like flowers and very long pods. The cultivated plant has a thick tap root which opens up the soil and which has numerous big nodules. visible on uprooting the plant. In the field, typical spots were selected side by side where *Sunn* and *dhaincha* grew and weighments were taken at two spots just before green manuring with the following results :

Survey No.	Weight of green matter per acre in lb.		Remarks
128 Baramati	*Dhaincha* 18,000	*Sunn* 8,690	Average of four tests

The above results establish the superiority of *dhaincha* over *sunn* green manuring.

Soil tests with *dhaincha* with graded growth were done and the results are given in Table XVIII along with crop conditions.

TABLE XVIII

Soil tests with dhaincha with graded growth

Serial No.	Crop condition	Height of crop	Capillary rise in cm. in 5 hours	Percentage of salt	*p*H value	Anna valuation
1	Very good	7 ft. 6 in.	7·6	0·92	7·85	14 to 15
2	Good	5 ft. 0 in.	7·2	1·07	8·05	10 to 14
3	Medium	4 ft. 0 in.	9·33	1·70	7·93	6 to 10
4	Poor	2 ft. 0 in.	10·0	1·88	7·65	4 to 6

Salt contents

The growth is very good even with high salt contents of 1·07 per cent. It shows deterioration at 1·88 per cent.

Plate XI fig. 2 shows the excellent growth of *dhaincha* in Survey No. 348 of Baramati salt Lands. It was the first crop taken after flooding and leaching done in the previous season.

The green weight of *dhaincha*, noted at the time of harvest, was recorded for varying salt contet in soil to a depth of 6 in. The results are given in Table XIX.

TABLE XIX

The green weight of Dhaincha for varying salt contents

Name of crop and description	Salt content in 6 in. layer of soil	pH value of soil	Green weight of *dhaincha* per acre in lb.
Dhaincha	0·5	8·52	40,397
Seed rate 80 lb.	0·7	8·64	35,840
Sown on 10-6-39	0·9	9·00	15,360
Harvested on 19-8-39	1·5	8·80	8,960
Three irrigations were given in all	3·0	8·60	5,120

The results fully bear out results given in Table XVIII

SUMMARY

(1) Mixed saline soils after leaching of soluble salts were suitable for growing crops. Addition of bulky manures were, however, necessary. Experiment showed that 30,000 lb. of farmyard manure or compost gave very good results and high yields were obtained, from 40 to 50 tons of cane per acre. An *adsali* crop, in a fully reclaimed area of this type, gave 86 tons of cane for CO 290 variety and 92·8 tons for POJ 2878 sugarcane varieties. This indirectly showed the potential capacity of the soil after complete improvement. It will be seen that sugarcane plays an important part in the reclamation process.

(2) Alkali soils of C_1 type required addition of calcium fertilisers (or sulphur) in addition to farmyard manure. Repeated treatments for three years at the time of planting completely restored such soils to their normal conditions.

(3) Alkali soils of C_2 type required special treatment of farmyard manure with a basal dose of three tons of gypsum with a *pachat* (dry leaves of cane) layer over it, covered with soil. Simultaneous green manuring with *dhaincha* was also advantageous. Planting was done in the buffer layer and the sugarcane crop was planted in monsoon (July or August). This facilitated leaching of alkali salts. Proper humidity and special layer of *pachat* gave very good start and the growth was maintained till harvest. Hence *adsali* crop is recommended for improving highly alkaline soils.

(4) Several varieties were tried in lands in process of reclamation and most promising ones were CO 290, CO 419, CO 417, and POJ 2878. Amongst the rotational crops, *dhaincha* succeeded very well. This was followed by varietal canes. After harvest cotton was dibbled. This crop improved the soil on account of its deep root system. Moreover cotton being an alkali resistant crop gave normal outturn and fetched a good revenue.

(5) Amongst other perennial crops, *shevari* appeared to be very promising; lucerne was next to it.

(6) Paddy was suitable for mixed saline soils, but did not thrive in stiff alkali soils of the Deccan.

ACKNOWLEDGEMENTS

The subsoil drainage and reclamation work was started under the guidance of Sir C. C. Inglis, when Executive Engineer, and was continued thereafter by Messrs. W. A. Evershed, I. S. E. and A. R. Thomas, I. S. E., Dr. V. K. Gokhale, Soil Physicist, conducted experiments up to 1930 after which the author was in direct charge of the experimental work. The author is indebted to all these and other officers and also to the present Executive Engineer, Rao Bahadur A. G. Maydeo, who went through this paper and gave valuable suggestions.

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STUDY OF MOVEMENT OF WATER AND SALTS IN SOILS AT THE AGRICULTURAL RESEARCH STATION, SAKRAND I

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(Received for publication on 1 March 1946)

SOIL moisture is one of the predominating limiting factor in crop production. In most of the cases it is the lack of moisture which affects the yield of the crop, yet in some cases it is the excess of moisture which causes water logged conditions which is responsible not only for the failure of the crop but also for accumulation of salts on the surface. In irrigated tracts both these conditions are likely to occur.

With the release of Barrage water very vast areas are brought under irrigation and investigations were started to study the distribution of soil moisture and salts in the soil.

Object of this paper is to study the movement of soil moisture in salt free and saline soils in irrigated, cultivated fields, its ultimate distribution and the depth and the rapidity of its penetration when applied in different doses.

This part deals with the soil moisture.

The work has been carried out at the Agricultural Research Station, Sakrand, between 1930-1935.

Soils of Sind

The soils of Sind are alluvial in origin, deep loamy and calcareous. A striking characteristic of these soils is the lack of uniformity over any distance, the surface soil varying so considerably from spot to spot that it has become proverbial.

There is rarely a difference in colour between the soil and sub-soil except that due to moisture. The profile is undefined and structureless without any stratification. Sandy layers and layers of clay of various thickness alternate with each other and are often impregnated with various amounts of salts.

These soils are rich in potash and phosphoric acid content. The nitrogen content is low but the deficiency is counterbalanced by the high capacity of the soils for the fixation of atmospheric nitrogen and nitrification.

The soils are poor in organic matters with low water holding capacity. The sub-soil water is struck at the depth of 20 to 30 ft. on the left bank of Indus while at the right bank of Indus the sub-soil water level is much nearer to the surface.

A study of the soil moisture under field conditions is no doubt a very complicated problem when one has to remember how complex the soil itself is and how many are the forces acting upon the soil moisture. The study of the soil moisture which is both diverse and intricate is for the purpose of investigation resolved into the following items :

(*a*) Vertical movement of water as affected by different doses of water
(*b*) Movement of water in cropped fields, and
(*c*) Movement of water as affected by the presence of salts in the soil

(*a*) *Vertical movement of water as affected by different doses of water*

To study the vertical movement of water, samples of soils up to depth of 6 to 10 ft. were collected from fields and moisture was determined in each sample before the supply of water and five days after the supply.

Measured quantities of water were given to all the beds. Water was measured in a measuring tank and brought to beds in *pucca* irrigation channels.

The soil samples were collected from layers of 0-1 ft., 1-2 ft., 2-3 ft., 3-4 ft., 4-5 ft., and 5-6 ft., samples were collected from three spots in a bed of 1/40th of an acre to make one composite sample. All the necessary precautions were taken while collecting samples for moisture studies. These samples were brought to the laboratory in glass bottles with screw caps. Moisture was determined in sample by heating 25 grm. of soil on an oven at 100-110°C. and finding the loss. The loss is expressed as percentage on oven dry soil. Some of the typical results are given in Table I. The nature of surface soil was loamy and of sub-soil was sandy loam.

TABLE I

Percentage of moisture in soil samples

Dose	4 acre inches		8 acre inches		12 acre inches	
	Before	After	Before	After	Before	After
	percentage of moisture		percentage of moisture		percentage of moisture	
0—1 ft.	3·8	15·2	1·7	19·2	11·8	23·3
1—2 ft.	4·2	12·6	3·0	16·4	8·7	25·7
2—3 ft.	5·2	7·6	6·9	20·5	8·8	27·5
3—4 ft.	5·4	4·0	9·4	11·6	7·5	31·7
4—5 ft.	6·7	7·7	15·7	17·0	12·5	24·8
5—6 ft.	16·3	16·0	4·6	4·6	18·6	22·8

Before—Sampling before addition of water

After—Samples taken five days after the last addition of water

Note.—4·0 acre inches of water were given in one dose. 8·0 acre inches were given in two doses of 4·0 in.; second dose was given after one day. 12·0 in. acre inches dose was given as under :

1st day—4·0 in.
2nd day—4·0 in.
5th day—4·0 in.

It will be seen from the figures given in Table I that within five days the downward movement of water extends to 3 and 4 ft. when the application of surface irrigation is 4 and 8 inches respectively. When the application is 12 in., the water goes beyond 6 ft.

(b) Movement of moisture in cropped lands

This has been studied with cotton crop. Movement of moisture in cotton fields has been studied from year to year commencing from 1931 to 1935. Cotton is sown by mid-May each year and the total quantity of water applied each year was as under :

(A) 46·5 in.
(B) 37·2 in.
(C) 31·0 in.
(D) 24·8 in.

Frequency of irrigation was as shown in Table II.

TABLE II

Frequency of irrigation

Treatment	Initial dose	Interval in days after the initial dose for subsequent irrigation and the dose of irrigation in inches								
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th
A	9/5	35	15	15	15	15	15	15	15	15
	(8·0)	(4·5)	(4·5)	(4·5)	(4·5)	(4·5)	(4·0)	(4·0)	(4·0)	(4·0)
B	9/5	35	15	15	15	15	15	15	15	15
	(8·0)	(3·4)	(3·4)	(3·2)	(3·2)	3·2)	(3·2)	(3·2)	(3·2)	(3·2)
C	9/5	35	15	15	15	15	15	15	15	15
	(8·0)	(3·0)	(2·5)	(2·5)	(2·5)	(2·5)	(2·5)	(2·5)	(2·5)	(2·5)
D	9/5	35	15	15	15	15	15	15	15	15
	(4·0)	(3·2)	(2·2)	(2·2)	(2·2)	(2·2)	(2·2)	(2·2)	(2·2)	(2·2)

Figures in brackets show the quantity of water applied in inches.

Samples of soil were collected at the following stages :

(1) Before the initial dose, *i.e.* 9/5.
(2) Five days after initial dose, *i.e.* 14/5.
(3) Before 1st irrigation, *i.e.* 16/6.
(4) Before 7th irrigation.
(5) After harvest in end December or beginning January.

Soil samples were collected from three spots in a bed to make a composite sample in layers of 0-1 ft., 1-2 ft., 2-3 ft., 3-4 ft., 4-5 ft., and 5-6 ft.

Surface soil was loamy in nature and sub-soil was sandy loam.

Some of the typical results obtained are indicated in Table III.

TABLE III

Movement of moisture in soil

Layer in ft.	Percentage of moisture					Total amount of water in in. added in form of irrigation
	At initial stage	After 5 days	Before 1st irrigation	Before 7th irrigation	At harvest time	Initial dose in in.
0—1	5·8	21·0	7·2	3·5	3·5	8·0	46·5
0—1	..	19·5	8·5	4·0	2·5	8·0	31·0
0—1	4·0	19·5	8·0	4·0	3·0	4·0	24·8
1—2	4·0	19·0	8·0	4·5	2·2	8·0	46·5
1—2	..	18·0	9·2	6·0	2·0	8·0	31·0
1—2	6·5	16·5	9·8	5·0	4·0	4·0	24·8
2—3	5·8	15·2	7·3	3·4	2·2	8·0	46·5
2—3	..	15·8	8·5	3·0	7·0	8·0	31·0
2—3	1·5	16·5	9·2	5·2	4·0	4·0	24·8
3—4	5·5	11·5	9·5	4·0	3·2	8·0	46·5
3—4	..	8·5	10·5	10·0	3·0	8·0	31·0
3—4	2·5	13·2	11·0	4·5	4·0	4·0	24·8
4—5	10·0	11·5	16·0	7·8	9·5	8·0	46·5
4—5	..	8·8	11·0	12·0	3·5	8·0	31·0
4—5	12·0	8·8	12·6	10·4	5·2	4·0	24·8
5—6	16·5	18·0	19·5	12·8	10·8	8·0	46·5
5—6	..	15·2	18·0	2·5	8·0	8·0	31·0
5—6	21·2	19·0	20·8	20·8	11·2	4·0	24·8

It will be seen from the figures given in Table III that whatever be the initial dose, the amount of water left in the soil is nearly constant and that the loss of water is mostly within first three feet during the first 35 days. As the growth of the cotton plant during this period is negligible, the cotton plant cannot be requiring all the water that is lost. It can therefore be deduced that the loss is mostly by evaporation. Because the amount of water left in the soil is nearly constant in first three feet in plots receiving 4·0 in. and 8·0 in., it could be said that the initial irrigation has little bearing on the moisture content of the first three feet of soil and that the evaporation is in direct proportion to the dose of water given.

As the crop grows, loss of water is seen up to a depth of 6 ft. This loss is mostly due to transpiration as the fields are mostly shaded due to the growth of crop at this period. The amount of water left in the soil by mid-September up to the fifth foot in different irrigational treatments is nearly constant. This indicates that loss of water by transpiration and evaporation is in direct proportion to the amount of water added.

Samples of soil collected at harvest time about three months after the last irrigation in mid-October indicate that whatever be the amount of irrigation, the soil is left poorer in moisture at harvest as compared to their original state.

Since the first three feet of soil are depleted of its moisture during the first 35 days and since with the higher soaking dose there is more loss of water due to evaporation, it becomes clear that it is not necessary to give a heavy soaking dose before sowing in normal soils.

(c) *Relative movement of water in salt-free lands and saline soils*

The above was studied in cotton fields in saline and salt-free soils as well as in pots.

Plots of land in salt-free and saline soil were made into uniform size and measured amounts of water was left in each lot. Moisture percentage was determined at regular intervals in both these soils which were cropped with cotton.

Surface and sub-soil were mostly identical in both the cases. Samples were collected up to depth of 3 ft. in layers of one feet each. Some of the typical results are given in Table IV.

TABLE IV

Movement of water in salt-free lands and saline soils

Nature of soil	Texture	Moisture percentage				Total loss	Salt percentage
		Initial After 5 days	After 10 days	After 20 days	After 25 days		
				0—1 ft. layer			
Sweet soil loam	4·5	24·0	14·5	10·8	12·5	11·5	·05—10
Saline soil loam	8·0	23·4	18·9	16·4	18·9	4·3	1·10
				1—2 ft. layer			
Sweet soil sandy loam	1·7	18·9	14·5	11·9	9·8	9·1	·05-0·10
Saline soil loam	7·8	25·1	21·8	21·8	21·2	3·9	1·30
				2—3 ft. layer			
Sweet soil loam	3·1	19·4	15·2	13·8	16·6	2·8	·05-10
Saline sandy loam	13·6	25·2	25·2	22·8	25·7	*Nil*	1·20

Pot culture experiments

Sodium chloride at 0·1, 0·2 and 0·3 per cent of the soil was mixed with sweet soil in soil free of salts. This soil was filled in empty kerosene tins and the moisture was brought to 25 per cent by the addition of water.

A similar set of tins was prepared but with sodium sulphate at 0·6 per cent of the soil and all the tins were then weighed periodically and the amount of water lost recorded. After a time the moisture in all the tins was again brought up to 25 per cent and the periodical determination of losses was repeated. Table V shows the results.

TABLE V

The loss of water in sweet and saline soils

Treatment	Moisture percentage								Total loss
	15/8	21/8	22/8	Total loss	23/8	25/8	27/8	29/8	
Control (Sweet soil)	25·0	15·0	14·0	11·0	25·0	19·0	15·0	13·0	12·0
Sodium chloride—									
0·1 per cent	25·0	15·0	15·0	10·0	25·0	20·0	13·5	14·0	11·0
0·2 per cent	25·0	19·0	17·0	8·0	25·0	22·0	18·0	17·0	8·0
0·3 per cent	25·0	20·0	17·5	7·5	25·0	22·5	20·5	17·5	7·5
Sodium sulphate—									
0·6 per cent	25·0	23·0	20·5	4·5	25·0	23·5	22·0	20·0	5·0

It will be seen from the figures in Table IV that there is more loss of water from sweet soil than saline soil and that the effect is more marked in the first two feet of the soil.

Results of pot culture studies given in Table V have borne out the same conclusion. Results in Table IV prove further that the loss of water varies inversely to the concentration of the salt.

It will be seen from the figures in Tables IV and V that in a given time sweet soil is left poorer in moisture than saline soils. Though there is more moisture in saline soils yet plants can not make use of it as it is not free to be lost. It can therefore be concluded that in identical conditions, more frequent water would be necessary in saline soils than in sweet soil to give identical normal crops.

Summary

The more is the application of water on the surface more is the downward movement of water in the soil.

During the first 35 days of the growth of cotton water is lost mostly by evaporation.

The evaporation is in direct proportion to the amount of water applied on the surface.

The water that is lost during the growing period of cotton by transpiration is in direct proportion to the amount of water applied.

Whatever be the amount of irrigation, the soil is left poorer in the moisture than the original state at the harvest time.

The presence of salts affect the loss of water from the soil due to evaporation and transpiration.

The loss of water is inversely proportional to the amount of salt.

Under identical conditions it is necessary to give more frequent irrigations to saline soils than to sweet soils to get identical normal crop.

The above work was conducted at Agricultural Research Station, Sakrand, under the guidance of the Agricultural Chemist and Soil Physicist, Agricultural Research Station Sakrand.

Acknowledgements

Author is thankful to Mr W. J. Jenkins, I.A.S., the then Chief Agricultural Officer in Sind and Rao Bahadur V. A. Tamhane, I.A.S., Agricultural Chemist and Soil Physicist, Sakrand, for their guidance. The author is grateful to Rai Bahadur R. L. Sethi, I.A.S., the present Director of Agriculture, for valuable criticism. Author is also thankful to Mr M. A. Sharma Iyengar, the then Senior Assistant for his valuable advice.

STUDY OF MOVEMENT OF WATER AND SALTS IN SOILS AT THE AGRICULTURAL RESEARCH STATION, SAKRAND—II

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(Received for publication on 1 March 1946)

IN Part I of this paper movement of moisture has been described. This part deals with the movement of salts.

It is a fact that one can hardly find an acre of land in Sind free from kalar patch. Beside these patches of kalar one comes across vast stretches of kalar lands in Sind. It was thought necessary to study the movement of salts that constitute kalar in soils. Kalar lands of Sind contain mostly salts of sodium chloride and sodium sulphate and sometimes chlorides of calcium and magnesium. Special feature of kalar soils of Sind is the absence of sodium carbonate and presence of calcium sulphate.

The typical composition of kalar is given below :

Place	Total soluble salts	Ca percentage	SO_4 percentage	Cl percentage
Left bank of Indus	3·40	0·31	1·4	0·81
Right bank of Indus	5·50	0·54	1·68	2·2

When water is applied to the soil the soluble salts, which are present in the soil, are dissolved and they move in all directions with water. They move downwards when there is a large quantity of water which percolates down. They come up to the surface by capillarity when the water is lost either by evaporation or transpiration. They also move horizontally and convert good lands into bad lands. It was therefore thought necessary to study the movement of salts in detail, as the knowledge of the movement of salts would be a great help in reclamation of saline soils.

Study of movement of salts for the purpose of investigation was resolved into the following items :

(1) Vertical movement of salts

(2) Rise of salts by capillarity, and

(3) Lateral movement of salts.

VERTICAL MOVEMENT OF SALTS

In series of plots different quantities of water were applied at the surface to see the effect of different doses of water on the downward movement of salts.

Soil samples were collected before and after the application of water up to a depth of 4 ft. in layers of 1 ft. each. Samples were collected from five spots to make a composite sample.

The nature of surface and sub-soil was nearly identical. The physical texture of the area under investigation was as under :

Layer	Sand	Salt	Clay
0—1 ft.	26·0 per cent.	42·0 per cent.	17·0 per cent.
1—2 ft.	24·0 ,,	48·0 ,,	17·0 ,,

The quantities of water and the system in which water was applied are shown in Table I.

TABLE I

The quantity of water and how it was applied

	Quantity of water in in.	How applied
A	6·0	All in one dose
B	8·0	All in one dose
C	12·0	6·0 in. once 6·0 in. afterwards on the third day
D	24·0	8·0 in. every week
E	32·0	8·0 in. every week

Some of the typical results are given in Table II.

TABLE II

The vertical downward movement of salt as a result of irrigation

Layer in ft.	Percentage of total Soluble salts		Quantity of water applied in in.
	Before application of water	5 days after application of water	
0—1	2·0	1·8	6·0
0—1	2·1	1·8	8·0
0—1	1·3	1·2	12·0
0—1	1·7	1·0	24·0
0—1	1·3	0·5	32·0
1—2	1·0	1·3	6·0
1—2	1·1	0·8	8·0
1—2	1·3	0·8	12·0
1—2	0·9	0·7	24·0
1—2	1·1	0·7	32·0
2—3	0·2	0·5	6·0
2—3	1·2	0·7	8·0
2—3	0·5	0·45	12·0
2—3	0·6	0·6	24·0
2—3	1·2	0·8	32·0
3—4	0·5	0·5	6·0
3—4	0·9	0·6	8·0
3—4	0·96	0·3	12·0
3—4	0·7	0·7	24·0
3—4	0·6	0·6	32·0

Figures in Table II indicate that the greater is the amount of water applied at the surface, the greater is the vertical downwards movement of salts. This indicates that in saline soils higher initial doses are beneficial to leach out salts from the surface and make the surface fit enough to carry normal crops.

Samples of moisture were taken up to a depth of 11 ft. in plots getting higher initial doses and it was observed there was no accumulation of water in the substrata. Readings of sub-soil water level in some of these plots showed that the sub-soil water level was not affected by the application of as high a dose as 32·0 in.

It was further observed that the movement of the chief sodium salts found in soil, viz. sodium chloride and sodium sulphate, is not the same with the same quantity of water. Results given in Table III below show the relative movement of sodium salts.

TABLE III

The relative amounts of sodium salts

Layer in ft.	Percentage of salts					
	Original		After leaching of 32·0 in. of water		After cotton harvest (8 months)	
	NaCl	Na_2SO_4	NaCl	Na_2SO_4	NaCl	Na_2SO_4
1	2	3	4	5	6	7
0—1	0·6	1·1	0·06	0·8	0·22	0·6
0—1	0·3	0·6	0·015	0·2	0·08	0·3
0—1	0·26	0·86	0·030	0·65	0·13	0·5
0—1	0·15	0·50	0·045	0·30	0·24	0·5

Figures given in Table III show that the sodium chloride is leached out prior to sodium sulphate and even in upward direction it is sodium chloride which comes up quicker than sodium sulphate. This phenomenon has been studied by many workers all over the world.

King [1904] says that the sodium sulphate is absorbed by the soil while sodium chloride is not. Headden [1903, 1918] also is of like opinion. According to Warrington [1900] soil has a slight retentive power for the acid radical of sulphate but none for nitrates, chlorides and carbonates.

Crowther and Basu [1931] found that nonovalent radicals rise by capillarity to the surface faster than divalent radicals. The phenomenon observed here agrees with the findings of research workers in the various parts of the world.

UPWARD MOVEMENTS OF SALTS

It is a common observation that the salts do come up to the surface by capillarity. In the present case such movement of salts within first 6 ft. was studdied at regular interval of 30 days in plots cropped with cotton and plots left fallow. Both these plots got the same amount of irrigation at the same time. Some of the typical results are given in Table IV.

TABLE IV

Upward movement of salts

Layer in in.	Percentge of total soluble salts				
	Initial	After 30 days	After 60 days	After 90 days	After 120 days
			Cropped plots		
0—6	1·1	1·3	1·1	1·3	1·1
6—12	1·1	0·8	1·0	0·7	0·6
12—24	1·0	0·7	0·8	0·6	0·7
24—42	0·7	0·6	0·6	0·6	0·6
42—60	0·6	0·6	0·9	0·5	0·5
60—72	0·7	0·7	0·8	0·7	0·7
			Fallow plots		
0—6	1·0	2·0	1·9	1·6	1·8
6—12	1·8	2·0	1·5	1·7	1·6
12—24	0·8	1·7	1·2	1·5	1·1
24—42	0·9	0·9	0·7	1·0	0·8
42—60	1·0	1·4	0·9	0·6	0·8
60—72	1·4	1·5	1·20	1·2	1·3

There is a well-known proverb in Sind that fallow makes sweet land better and kalar lands worse. This is borne out from figures given in Table IV.

Since the process of accumulation of salts is reduced by cropping, it will be an advantageous and economical proposition if kalar lands, once brought under cultivation, are cropped continuously for some years till the salt content is reduced to such an extent as to permit plant growth.

Lateral movement of salts

It is a common observation in Sind that strips of land stretching from either sides of the canals and water courses become infested with salts in course of time and that lands when brought under irrigation develop kalar and become infertile. These phenomenon are obviously due to certain movements of salts in soil under the influence and help of irrigation water.

It is known that salts freely move upwards and downwards with the movement of water but the extent to which salts move laterally is not definitely known. Experiments were conducted at the Agricultural Research Station, Sakrand, to study if the salts move laterally and if so to determine the rates of migration.

The procedure

A pit 1½ ft. × 1½ ft. × 1½ ft. was dug in sweet soil of sandy loam texture and the bottom of the pit was cemented so as not to allow any water to percolate down from the bottom of the pit. Two trenches, A and B, 10 ft. long and 1½ ft. deep, were dug on the east and the south of the pit and at right angles to each other. The bottom of the trenches was then cemented and again filled with soil and rammed. The other two sides of the pit were left in natural condition. The pit was then filled with 0·5 per cent solution of commercial potassium chromate. After preliminary trials this salt was selected for the experiment for the following reasons :

(1) Its absence in the soil
(2) Its high solubility
(3) Its low absorption by the soil
(4) Its easy detection in the soil extract by qualitative analysis, and
(5) Its yellow colour which helps to identify it as it travels further from the source.

Potassium permanganate was also tried but it was considerably absorbed by the soil, it was affected by the organic matter in the soil and its qualitative determination was not so easy.

Constant level of solution was maintained in the pit by addition of fresh solution whenever required. At the intervals of a month, samples of soil up to 18 in. depth were taken along the cemented and undisturbed sides, at distances of one foot from the edge of the pit, and each of the samples was tested for potassium chromate. From the distances travelled and time taken to travel those distances, the rate and extent of lateral migration of the salt in the soil were arrived at.

Table V

Lateral migration of potassium chromate

No. of days after start	Date of Sampling	Total distances in ft. travelled in different sides from the edge of the pit				Remarks
		A	B	C	D	
15	17-3-31	2	3	2	2	
46	17-4-31	3	3	3	4	
75	14-5-31	3	3	5	5	Rain fall 0·01 in.
121	1-7-31	4	4	5	5	,, 1·89 ,,
148	29-7-31	6	6	6	5	,, 0·90 ,,
170	28-8-31	6	6	6	6	

It would be seen from the results given in Table V that salts move laterally and that the lateral movement is greatest in the first two weeks. It then goes on decreasing till the 73rd day after which the movement of salts is very little. In sandy loam the average movement of salts is 1 foot per month provided that there is a constant head of water. It is also observed that after period of six months the lateral movement of salts is rather little. While attempting reclamation by heavy doses of water good lands should be separated from kalar lands by means of drain or any other device so that salts do not move laterally from kalar lands to good land.

Summary

The more water is applied on the surface, the more washing down of salts from the surface layer is effected. Application of 32·0 in. on the surface depletes the surface soils of soluble salts and makes it fit for general cultivation. Of the injurious salts, the more injurious sodium chloride is washed down more quickly than the less injurious sodium sulphate. Salts once washed down come up to the surface, the more injurious sodium chloride comes up more quickly than the less injurious sodium sulphate, but cropping retards the rise of salts. Saline soils should therefore be kept under continuous cropping during the process of reclamation.

It is proved that the salts move laterally and the method of studying the lateral movement of salts is described.

The above work was conducted at the Agricultural Research Station, Sakrand, between 1930-1935 under the guidance of the Agricultural Chemist and Soil Physicist, Agricultural Research Station, Sakrand.

Acknowledgements

The author is thankful to Mr W. J. Jenkins, I.A.S., the then Chief Agricultural Officer in Sind and Rao Bahadur V. A. Tamhane, I.A.S., the then Agricultural Chemist and Soil Physicist, Agricultural Research Station, Sakrand, for their valuable guidance. Author is grateful to Rai Bahadur R. L. Sethi, I.A.S., Director of Agriculture Sind, for his valuable criticism. Author is thankful to Mr M. A. Sharma Iyengar, the then Senior Assistant, for his valuable advice.

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CANNING TRIALS ON FRUITS

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(Received for publication on 21 March 1947)

OUT of the factors responsible for the success of the fruit canning industry, production of a canned product of uniform high quality is very important. This can be achieved by canning sound and fully ripe fruit of varieties best suited for the purpose. Since it is known that all varieties of a fruit are not suitable for canning, resort has to be made for conducting small scale canning trials for the selection of varieties suitable for canning. Such trials are of vital importance for a successful venture in the canning line in our country, where literature regarding the suitability of different varieties of fruits for canning is scanty.

A good canning variety of any fruit must have suitably firm texture and fully developed characteristic aroma of the fruit, so that minimum change is effected in the real characteristics of the original fruit during the process of canning. Selection of varieties like early, late, etc. is also important from the point of view of spreading the canning season over as long a period as possible.

Among the fruits canned in California [Cruess, 1938], peaches, apricots and pears are most common, and a good deal of work has been done there in the way of selection of suitable canning varieties of these fruits. In India although a fairly large number of varieties (both local and imported) of various fruits are at present grown in different parts of the country, no systematic work has so far been carried out for determining their canning quality, except at Quetta [Siddappa, 1942], on the canning of apricots grown in Baluchistan, and at Lyallpur [Lal Singh and Girdhari Lal, 1944], on canning of pears, grown in Kulu (Punjab). It is hoped that the present article which deals with the canning trials carried out in the Fruit Products Laboratories, Lyallpur, on the important commercial varieties of plum, peach, apricot and pear grown in the United Provinces [Saharanpur and Chaubattia (Kumaon Hill) Circles], Kashmir and Punjab (Palampur), will contribute to this end. This investigation was started in 1941, at the instance of the Supply Department (Government of India), with a view to select good canning varieties of these fruits, grown in different localities.

Material

Fruit. The fruit used for canning should be fully ripe and must have developed, as much as possible, the characteristic tree ripe flavour; but it should not be too soft and over-ripe, as such fruit does not stand preparation and processing during canning. In most cases fruit is picked at firm 'ripe' stage, when the colour has fully developed but before it acquires softness associated with the ripe dessert stage [Hirst and Adams, 1936], and, as far as possible, it is canned the same day. This requires the fruit to be quickly transported from the farm to the cannery.

In the present investigation great difficulty was experienced in getting the fruit of uniform stage of ripeness. As the fruit had to be transported over fairly long distances; some of the consignments arrived in an unsatisfactory condition, i.e. the fruit was not uniformly ripe. Out of each consignment a fair proportion of fruit had to be rejected while selecting the right type of fruit for canning. It was due to the facilities of cold storage available in these laboratories that the canning trials were possible. Hard but fully developed fruits were allowed in each case to ripen in cold storage (temperature 60-70°F.) until these became fit for canning. Due care was also taken in the final selection of fruits used in canning.

Fourteen different varieties of plum, ten of peach, five of apricot and three of pear were used in these trials. Names of these varieties along with the source of their origin are given in Table I.

General characteristics like colour, size, number of fruits per pound, etc. of the different varieties, which have been tested, are given in Table II, which is self-explanatory. Peaches were mostly freestone type, most of the varieties being white fleshed. Plum varieties were red, purple, golden and greenish, and of varying sizes. Apricots were yellow except one white variety, obtained locally

(produce of Quetta). In California, Williams' is the most common out of pears, and yellow varieties of apricots are preferred to white ones. Plums used are of red varieties, but there is good demand for golden ones also. Peaches are generally yellow-coloured clingstone varieties, but recently interest has been shown in the canning of freestone varieties also [Mottern and Neubert, 1940; and Caldwell and Culpepper, 1944].

TABLE I

Varieties of plum, peach, apricot and pear used in canning trials

Serial No.	Fruit Varieties				Locality
	Plums	Peaches	Apricots	Pears	
1	Alfa	(1) Bidwill's Early (Clingstone).	..	1. Leconte	Saharanpur (United Provinces)
2	Alubukhara (plum) large	(2) Country (freestone)	..	..	Do.
3	Ladak	....	..	..	Do.
4	Howe	....	..	..	Do.
5	Excelsior	....	..	..	Do.
6	French Red	....	..	..	Do.
7	Kelsey's Japan	....	..	..	Do.
8	Satsuma	(3) "Quetta"	1. Large	2. Williams'	Kashmir
9	Yellow Prune	....	2. Small	3. X'mas	Do.
10	Victoria	....	..	..	Do.
11	Chabot	....	..	..	Palampur (Punjab)
12	Satsuma	....	..	..	Do.
13	Merriposa	....	..	..	Do.
14	Jefferson	(4) Foster	3. Large early	..	Chaubattia (United Provinces)
15	....	(5) Red Nectarine	4. Turkey	..	Do.
16	....	(6) Alton (freestone)	..	..	Do.
17	....	(7) Carmon (freestone)	..	..	Do.
18	....	(8) Fitzgerald (freestone)	..	..	Do.
19	....	(9) English gland (freestone)	..	..	Do.
20	....	(10) Princess of Wales (freestone)	..	..	Do.
21	....	....	5. Charmagaz	..	Quetta (Baluchistan)

TABLE II

Characteristics of the fresh fruits

Serial No.	Name of variety	No. of fruits per lb.	Physical characteristics
		1. Plums	
1	Alfa	45—47	Small sized red plum
2	Ladak	34—37	Small sized, texture rather hard; colour greenish yellow with reddish tinge
3	Howe	30	Medium sized, rather hard, unripe and sour; colour reddish yellow
4	Alubukhara (plum) Large	34—37	Small sized plum of straw yellow colour
5	Excelsior	31—37	Small sized, rather hard and unripe; colour greenish red
6	French red	32—54 (average 43)	Small sized, lacking sweetness; reddish colour
7	Kelsey's Japan	13—18 (average 15)	Fairly big size, very hard and perfectly raw; green colour. Did not mature completely and properly even in two weeks in cold storage, but acquired only slight yellowishness and softness
8	Satsuma (Kashmir)	18—19	Fair size, rather hard; colour greenish to purplish crimson. Ripened to crimson colour in cold storage

Serial No.	Name of variety	No. of fruits per lb.	Physical characteristics
9	Yellow Prune	22—23	Fair size, rather hard, under ripe and sour; colour deep brownish. Ripened and softened well in cold storage and developed good taste
10	Victoria	9—10	Big size, skin tough; colour of skin dark purple, flesh yellowish; taste astringent and sour. Flavour did not develop even after one week in cold storage
11	Chabot	14—15 (average 15)	Fairly big size, good texture; golden yellow colour with red flush on surface. Matured very well in cold storage
12	Merriposa	..	Big size, texture good; skin rather dull reddish but flesh of deep red colour, good quality
13	Satsuma (Palampur)	13—17 (average 15)	Fairly big size, texture good; red colour, and good general quality
14	Jefferson	13—17 (average 15)	Fairly big size, unripe; ripened to yellowish colour in cold storage
		2. *Peaches*	
1	Bidwill's Early	..	Average sized, white clingstone variety
2	Country	..	Average sized, freestone, pinkish green colour
3	Foster	6—8	Average sized, freestone, texture not firm, golden yellow colour
4	Red Nectarine	6—7	Average sized, freestone, pale yellowish green colour
5	Alton	About 7	Average sized, freestone, rather greenish colour
6	Carmon	6—7	Average sized, freestone; yellowish colour with red flush, flesh pinkish. Deep depression at stalk end
7	Fitzgerald	6—7	Average sized, freestone; golden yellow colour with red flush and mealy bloom on surface, flesh pale yellow and slightly sour
8	Englishgland	9—10	Small sized, freestone, rather unripe and hard; pale yellow colour with tinge of green and red flush
9	Princess of Wales	4—6	Fairly big sized, freestone; pale yellowish green colour with pink flush. Stone cavity deep and of pink colour. Skin thick and tough, flesh pale white and rather sour
10	Quetta	6—7	Medium sized, freestone; yellow colour with red flush. Skin thin, free and tender; flesh tender, very good and of golden yellow colour
		3. *Apricots*	
1	Large Early	About 20	Average sized, freestone; golden yellow colour
2	Turkey	About 20	Average sized, freestone; straw coloured
3	Charmagaz	18—20	Average sized, freestone; light pale yellow colour
4	Large	About 9	Big sized, freestone; golden yellow colour, fully ripe and rather soft
5	Small	25—26	Small sized, clingstone; golden yellow colour, fully ripe
		4. *Pears*	
1	Leconte	4—5	Fairly good size, greenish colour; not quite soft and fully ripe; lacking in sweetness and flavour; core very hard and stiff
2	Williams'	3—4	Normal size, bright yellow colour after ripening in cold storage and crimson flush on some fruits. Flesh sweet, creamy and juicy, texture firm and flavour good
3	X-mas	2—3	Big sized, yellow colour with light pink flush on some fruits. Flesh rather crisp and dry and not creamy and juicy, lacking in flavour; texture grainy and fibrous

Cans. Fruit-lacquered and plain tin cans with sanitary double seams, are used in canning. Lacquered ones are at present common for canning highly coloured fruits, since even traces of metal dissolved from the plain can wall by the action of the acid on the tin plate, will spoil the colour and appearance of the pack. Pears, apricots and peaches are little affected but blackberries, straw berries, etc. are easily spoilt [Osman and Jones, 1941]. Both lacquered and plain tin cans were,

therefore, used for plums, peaches and apricots, in these tests to find out the difference in the behaviour of these. Pears, however, were canned only in plain cans since lacquered ones are known to suffer badly from pin holing due to the formation of hydrogen swells. The cans before use were washed thoroughly with hot water to remove zinc chloride and destroy bacteria [Anon, 1937].

Sugar. Ordinary white crystalline sugar as available in the market was used for preparing canning syrup required for experiments under this investigation.

Methods

Methods used in other countries for the commercial canning of plums, peaches, apricots and pears are highly standardized and have been described by Cruess [1938] and Campbell [1937]. The same methods with slight modifications were, in general, followed throughout the investigation. All the varieties of the same fruit were canned under similar conditions. Colour and general appearance of the fruit and the beginning of softness were used as indices of maturity. Grading was done by hand. Syrup used for the canning of each of the fruits was of the same concentration as used in the 'fancy' grades commercially packed in California and eleswhere [Cruess, 1938].

Plums. These were canned 'whole', as usual, after washing them thoroughly with water, in 40° Brix syrup. Skin of the plums invariably bursts during canning [Anon, 1935]. This defect is claimed to be prevented by pricking the fruit with needles prior to canning [Campbell, 1937]. This treatment was tried with some varieties but results were not very satisfactory as the skin even after pricking did show signs of cracking on subsequent examination of the canned product.

Peaches. The fruits were halved by cutting round the suture line. Pits were removed with special pitting spoons and halves placed in a wire gauze basket, were peeled by subjecting them to the action of a boiling 1-2 per cent lye solution for 25 to 40 seconds, in order to cauterize the skin. These were then washed thoroughly in running cold water to remove the peels and excess of lye. After rinsing in 0·35 per cent HCl solution, they were again washed, drained and immediately canned in 55° Brix sugar syrup.

Apricots. The fruits after washing were split into halves like peaches and canned in 55 Brix sugar syrup.

Pears. The fruits were peeled by hand with a special guarded curved knife. The halves until canned were kept in 1·25 per cent common salt solution, to prevent browning. These were washed and canned in 40° Brix sugar syrup.

Processing.—The cans as described under the heading 'Material' were filled with the fruit according to the usual standards. Hot sugar syrup (Table III) was then added and the cans exhausted in stationary kettles for small lots and in a continuous exhauster for bigger lots [Lal Singh and Girdhari Lal, 1941]. These were then sealed immediately with a double seamer and sterilized in stationary cooking tanks, after which they were cooled to avoid overcooking [Anon, 1937]. Pears were cooled thoroughly in iced water to prevent their turning pink in the can. The exhausting and processing times required in each case are given in Table III.

Table III

The density of canning syrup, and exhaust and processing times in canned fruits

Fruit	Size of can	Density of syrup (Brix°)	Exhaust in (minutes) and temperature	Processing times in minutes at 212°F.	Remarks
Plums	A 2	40	6 at 200°F	10—12	Cooled in water to 100°F. and then stacked
	A 2½	40	8 at 200°F.	15—18	
Peaches	A 2	55	6 at 180—190°F.	20	Water cooled to room temperature and then stacked
	A 2½	55	10 at 180—190°F.	25	
Pears	A 2	40	6 at 180—190°F.	25	Chilled in iced water and then stacked
	A 2½	40	8 at 180—190°F.	30	
Apricots	A 2	55	6 at 180—190°F.	15	Allowed to cool gradually in air
	A 2½	55	8 at 180—190°F.	25	

Cut out Examination

The canned products were examined periodically during a total storate period of over two years, according to the standard cut-out technique of Hirst and Adams [1932]. This consisted of determining the vacuum, gross weight, weight of contents and density of syrup, noting the condition of can, appearance of fruit and syrup, and testing the quantity of the product regarding colour, texture, preparation, taste and flavour, etc. The fruit for this purpose was examined by spreading it on a 15 mesh sieve made of wire of about 0·016 in. diameter, and draining for five minutes. Results of a typical cut-out test of some of the varieties are presented in Table IV.

Table IV

Results of Cut-out tests of important varieties of plum, peach, apricot and pear, carried out during storage

Serial No.	Name and variety of fruit	Date of canning	Date of inspection	Description of can	Gross wt. (gm.)	Vacuum in inches of Hg.	Internal condition of can	Total contents (gm.)	Drained wt. of fruit (gm.)	Cut-out strength of syrup (degrees brix at 68°F.)
	Plums									
1	*Alubukhara* (plum) Large	11-6-41	1-4-42	A2P	703·5	7·5	Heavy feathering of tin plate	595·7	261·2	23·62
				A2L	641·0	..	Lacquer somewhat corroded	541·0	254·5	23·62
2	Ladak	14-6-41	1-4-42	A2P	719·5	4·5	Heavy feathering of tin plate	617·8	288·6	27·64
				A2L	714·0	2·0	Slight corrosion of lacquer	606·3	295·3	28·64
3	Howe	16-6-41	1-4-42	A2½P	1033·0	8·0	Heavy feathering of tin plate	908·8	425·3	23·63
				A2L	693·8	6·0	Lacquer not affected	592·8	294·0	23·62
4	Kelsey's Japan	30-6-41	1-4-42	A2½P	1018·0	16·5	Heavy feathering and slight blackening of tin plate	883·0	510·0	27·64
				A2L	683·0	19·30	Lacquer intact	574·0	273·5	25·63
5	Satsuma (Kashmir)	9-8-41	2-4-42	A2P	705·2	8·5	Heavy feathering and slight blackening	596·2	313·5	26·99
				A2L	676·0	5·5	Lacquer fairly corroded	570·0	295·0	27·99
6	Yellow Prune	9-8-41	2-4-42	A2½P	1037·0	10·0	Feathering of tin plate	897·0	379·0	32·50
				A2½L	1030·0	12·0	Lacquer intact	886·0	363·0	31·50
7	Chabot	3-7-43	10-5-44	A2L	660·0	7·0	Slight corrosion of lacquer	555·0	295·0	27·21
8	Satsuma (Palampur)	7-7-43	10-5-44	A2P	683·0	10·0	Fair amount of feathering of tin plate, colour changed to steel grey	579·0	311·0	27·24
				A2L	698·0	13·0	Fair corrosion of lacquer, otherwise shining	593·0	312	27·22

TABLE IV—*contd.*

Results of Cut-out tests of important varieties of plum, peach, apricot and pear, carried out during storage—contd.

Serial No.	Name and variety of fruit	Date of canning	Date of inspection	Description of can	Gross wt. (gm.)	Vacuum in inches of Hg.	Internal condition of can	Total contents (gm.)	Drained wt. of fruit (gm.)	Cut-out strength of syrup (degrees Brix at 68°F.)
9	Merriposa . .	29-6-43	10-5-44	A2P	688·0	9·0	Fair feathering, dark steel grey colour of tin plate	583·0	279·0	27·20
				A2L	703·0	15·0	Slight corrosion of lacquer . .	597·0	204·0	27·26
	Peaches									
10	Fitzgerald . .	14-7-41	5-10-42	A2½P	1040·0	10·0	Fair feathering and blackening of tin plate	907·0	492·5	32·12
				A2L	718·0	8·0	Lacquer fairly corroded	609·5	337·5	30·60
11	'Quetta' .	23-8-41	5-10-42	A2P	725·0	12·0	Fair feathering and blackening of tin plate	615·0	379·5	29·58
				A2½L	1046·5	9·0	Lacquer corroded to a fair degree	916·5	496·0	29·58
	Apricots									
12	Charmagaz .	7-6-41	24-1-42	A2½L	1068·0	11·5	Slight corrosion of the lacquer	924·5	407·5	35·82
				A2P	721·0	12·5	Feathering of tin plate	616·0	273·0	32·82
	Pears									
13	Williams . .	22-8-41	4-4-42	A2P	702·0	11·0	Feathering of tin plate	597·0	325·0	29·56

L = Lacquered cans
P = Plain cans

No. of fruits or pieces	Appearance		Firmness	General quality, taste and flavour	Remarks
	Fruit	Syrup			
30	Skin burst, golden yellow colour, attractive appearance	Fairly clear	Fairly firm . .	Skin rather hard, taste and flavour fairly good	
31	Ditto . .	Ditto . . .	Ditto .	Ditto	
30	Skin and flesh somewhat burst, attractive golden yellow colour	Ditto . . .	Ditto .	Skin rather hard, flesh fair; taste and flavour very good	
28	Ditto . .	Ditto . . .	Ditto .	Ditto	
35	Rather discoloured (brownish) and not very attractive colour; otherwise good	Ditto . . .	Good . .	Good	
26	Brownish colour, otherwise good	Ditto . . .	Do. . .	Do.	
15	Skin and flesh somewhat burst, attractive greenish yellow colour	Clear	Rather hard .	Flesh and skin very good in eating although slightly hard; rather lacking in sweetness, otherwise taste and flavour good	
12	Ditto . .	Do	Ditto .	Ditto	

TABLE IV—*concld.*

Results of Cut-out tests of important varieties of plum, peach, apricot and pear, carried out during storage—concld.

No. of fruits or pieces	Appearance		Firmness	General quality, taste and flavour	Remarks
	Fruit	Syrup			
10	Skin rather burst, fruit discoloured changing to dull brownish violet	Dull violetish unattractive colour; otherwise fairly clear	Fairly firm	Excepting slight acidity, taste and flavour good; flesh very good in eating	
10	Skin somewhat cracked, colour better than above	Fairly clear, bright deep red colour	Ditto	Ditto	
22	Skin, burst, otherwise good; attractive brownish yellow colour, flesh of bright yellow colour	Dull pinkish colour, otherwise fairly clear	Quite firm	Skin slightly hard otherwise good and pleasant in eating; flesh very good. Taste and flavour very good	It can give excellent product if canned after peeling
23	Ditto	Attractive, bright deep pinkish colour; clear	Ditto	Ditto	
13	Skin removed, otherwise appearance good; attractive golden yellow colour	Rather turbid, but colour attractive brownish yellow	Slightly soft	Eating quality and texture very good, taste and flavour excellent	
11	Good brownish violet colour, attractive appearance	Fairly clear, reddish colour	Good	Texture and flesh of fruit and eating quality very good; taste and flavour very good	
10	Good reddish colour, attractive appearance	Clear; deep red colour	Do.	Ditto	
7	Rather dull brownish colour, otherwise very good in appearance	Rather dull light pinkish colour; fairly clear	Fairly good	Ditto	
7	Good attractive bright brownish colour and very good appearance	Red coloured clear syrup	Ditto	Ditto	
10	Very good and attractive appearace, golden yellow colour	Clear of light pale yellow colour	Slightly hard	Except for slight hardness, flesh and eating quality very good. Taste and flavour very good	
8	Ditto	Ditto	Ditto	Ditto	
16 pieces	Very good attractive appearance; soft ripe fruit of deep orange yellow colour	Except for slight suspended fruit particles, syrup clear	Fairly good	Flesh and eating quality very good; taste and flavour very good	
30 pieces	Ditto	Ditto	Ditto	Ditto	
43 halves	Condition of fruit very good; halves of bright attractive colour and appearance	Fairly clear, light yellow colour	Good	Skin and fibre somewhat hard, good and pleasant in eating. Taste and flavour very good and natural	
30 halves	Ditto	Ditto	Do.	Ditto	
7 halves	Very slight violet tinge in colour, appearance very good and attractive	Fairly clear	Do.	Texture very good and soft, pleasant eating quality; flavour and taste very good	

DISCUSSION OF RESULTS

As a result of the above cut-out examinations, the best canning varieties of the different fruits, viz. plums, peaches, apricots and pears, as reported in this article along with their places of origin, are given in Table V.

Plum. As seen from Table V, varieties of plum like Alubukhara (plum) Large, Ladak, Howe, Kelsey's Japan (United Provinces); Satsuma, Yellow prune (Kashmir); Chabot, Satsuma, Merriposa (Palampur), were found to be good canners. Out of these, Chabot, Satsuma and Yellow prune varieties gave comparatively the best product. Kelsey's Japan would have given a very good

product, but it did not, since the fruit was rather raw and never attained its full maturity even during storage, therefore remaining hard after canning with low sugar penetration; yet in spite of these it yielded a reasonably good product. For the same reasons 'Victoria' variety did not yield a suitable canned product, although it is known to be a good canner [Hirst and Adams, 1936]. It is therefore presumed that if picked at the right stage of maturity, it would yield a canned product of good quality.

TABLE V

Best Canning varieties of plum, peach, apricot and pear

Fruit	Varieties	Place of origin
1. Plum	1. *Alubukhara* (plum) Large	Saharanpur (United Provinces)
	2. Ladak	Ditto
	3. Howe	Ditto
	4. Kelsey's Japan	Ditto
	5. Satsuma	Kashmir
	6. Yellow Prune	Ditto
	7. Chabot	Palampur (Punjab)
	8. Satsuma	Ditto
	9. Merriposa	Ditto
2. Peach	1. 'Quetta'	Kashmir
	2. Fitzgerald	Chaubattia (United Provinces)
3. Apricot	1. Charmagaz	Obtained locally (produce of Quetta, Baluchistan)
4. Pear	1. Williams'	Kashmir

Original colour of canned plums in all cases underwent marked adverse changes during storage. In general, colour retention was better in lacquered cans than in plain ones. Lacquered cans on the other hand suffered from a fair degree of corrosion which subsequently caused pinholing and perforations. This was first observed after about 7-9 months' storage and continued to a varying degree in nine varieties out of the fourteen tried. It may be mentioned here that experiments which were exclusively carried out in these laboratories [Anon, 1942-43 and 1943-44] on the formation of hydrogen swells in different fruits, indicated that in a period of about two years' storage, percentage spoilage due to hydrogen swell formation in the case of plums was to the extent of about 18·0 per cent.

Spoilage due to pin-holing and hydrogen swell formation is directly connected with cracks produced in the lacquer coating during can reforming, however carefully it may be done. The latest technique of lacquering cans after fabrication ('post' or 'flush' lacquering), has been claimed by Hirst and Adams [1939] to provide complete protection against hydrogen swells for about three years under normal conditions. In the absence of these 'flush lacquered' cans, it would appear that colour and appearance of plums may have to be sacrificed by using plain cans instead of those lacquered in the ordinary manner, for packing this fruit for storage over more than six months.

Peaches. Two yellow varieties, namely 'Quetta' and Fitzgerald proved to be the best canners. Foster, and Red Nectarine were promising up to about four months' storage but deteriorated during subsequent storage. Plain as well as lacquered cans behaved almost similarly regarding appearance, taste, etc. of peaches. Product in lacquered cans suffered from hydrogen swells which ultimately caused pin-holing. This was observed after one year's storage in only four varieties and to a lesser extent than in plums. In experiments exclusively conducted on hydrogen swell formation [Anon, 1942-43 and 1943-44] spoilage due to this trouble was to the extent of about 4·0 per cent in about two years' storage.

Apricots. Only 'Charmagaz' yielded a product of good quality, others became fairly mashy during canning and had an acidic taste. No difference was noticed in the general quality of the product packed in plain or lacquered cans. Plain cans showed a fairly high degree of feathering and

lacquered ones slight corrosion of lacquer which was more pronounced in the yellow varieties. Pinholing was observed in three varieties packed in lacquered cans, after about 17 months' storage.

Pears. Only Williams' proved to be a good canner and gave a product of excellent texture, flavour and taste; other varieties lacked in these characteristics. This variety as grown in Kulu valley (Punjab) has also been found to be a good canner by Lal Singh and Girdhari Lal [1941, 1944]. It has also been reported by Hirst and Adams [1936] to be an extensively canned variety of pear in California.

Summary

Trials have been carried out on the canning of fourteen varieties of plum, ten of peach, five of apricot and three of pear, grown in the United Provinces (Chaubattia and Saharanpur circles), Kashmir and the Punjab with a view to select good canning varieties of these fruits. Data on the physical characteristics of fruit of all the varieties such as size, colour, number of fruits per pound, etc., have been given. Behaviour of these in plain as well as lacquered cans during a storage period of about two years has been discussed. Out of all the varieties, Alubukhara (plum) Large, Ladak, Howe, Kelsey's Japan (Saharanpur), Satsuma, Yellow prune (Kashmir), Chabot, Satsuma and Merriposa (Palampur) varieties of plum, 'Quetta' (Kashmir) and Fitzgerald (Chaubattia) varieties of peach, 'Charmagaz' (obtained locally produce of Quetta) variety of apricot and Williams' (Kashmir) variety of pear have been found to be good canners. The results of typical cut-out tests of all these varieties have also been given.

Acknowledgments

The authors wish to express their thanks to Sardar Bahadur Sardar Lal Singh, Fruit Development Adviser to the Government of India (formerly, Fruit Specialist, Punjab) for his valuable suggestions and criticism during the course of this investigation and to the Imperial Council of Agricultural Research for the research grant to the scheme under which this work was carried out.

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PLANT QUARANTINE NOTIFICATIONS

Plant Quarantine Notifications of the Government of India, Department of Agriculture, Bureau of Plant Protection and Quarantines

Notice No. 2 of 1946

Notifications of Foreign Quarantine Restrictions received during July-December, 1946.

The following Plant Quarantine Notifications have been received in the Bureau. Those interested are advised to apply for details to the Plant Protection Adviser to the Government of India.

1. Plant—Quarantine Import Notifications of the Dominion Republic; B. E. P. Q. No. 396—Supplement No. 3, dated 22nd August, 1946, issued by the U. S. Dept. of Agriculture.	Prohibiting importation of tomato and Pepper Seed into the Dominion Republic without certificates of Disinfection with mercury compounds to prevent the introduction of the "Bacterial Spot".
2. Plant—Quarantine Import Notifications of the United Kingdom of Great Britain; B. E. P. Q. No. 416, Supplement No. 2, dated 22nd August, 1946, issued by the U. S. Dept. of Agriculture.	Regarding restrictions of importation of Raw Cherriers into Scotland after 18th May from any country other than Belgium, France or the Netherlands to prevent the introduction of the Cherry Fruit Fly. A similar restriction has been placed by the Ministry of Agriculture and Fisheries in regard to the import of cherries into England walls after the 27th May, 1946 from France, according to the Int. Bull. of Plant Protection, Rome, October, 1946.
3. Plant—Quarantine Import Notification of the Union of South Africa B. E. P. Q. No. 47, Supplement No. 4, dated the 22nd August, 1946, issued by the U. S. Dept. of Agriculture.	Notifying a revision of regulations concerning citrus fruits potatoes, etc.
4. Plant—Quarantine Import Notifications of Newfoundland B. E. P. Q. No. 554, dated 22nd August 1946, issued by the U. S. Department of Agricutlure.	Although Newfoundland has no plant quarantine regulations, certification, is required with all importation of plants and seeds.
5. Plant—Quarantine Import Restrictions of the Union of Soviet Socialist Republics; B. E. P. Q. No. 425—Revised, dated the 26th August, 1946, issued by the U. S. Department of Agriculture.	Contains a summary of the plant-quarantine import restrictions of the U. S. S. R. for the information of importers, etc.
6. Plant—Quarantine Import Restrictions of the Republic of Venezuela, B. E. P. Q. No. 497—Revised, dated the 30th August, 1946, issued by the U. S. Department of Agriculture.	A digest of the plant-quarantine import restriction of the Republic of Venezuela for the information of nurserymen, etc.
7. Plant—Quarantine Import Restrictions of the Republic of Uruguay; B. E. P. Q. No. 382—Supplement No. 1—Revised, dated the 27th September, 1946, issued by the U. S. Department of Agriculture.	Deals with revised restrictions on the importation of seed potatoes into Uruguay.
8. Plant—Quarantine Import Restrictions of the French Zone of Morocco; B. E. P. Q. No. 444, 2nd Revision; dated 4th November, 1946, issued by the U. S. A. Department of Agriculture.	This is a revision of the digest of the plant-quarantine import restrictions of the French Zone of Morocco for the use of nurserymen, plant-quarantine officials and others.

The following notification pertaining to the period January to June 1946 was received too late for inclusion in Notice No. 1 of 1946.

9. Plant—Quarantine Import Restrictions of the Colony of Mozambique; B. E. P. Q. No. 550, dated 23rd April, 1946; issued by the U. S. A. Department of Agriculture.	A summary of the plant quarantine import restrictions of the Colony of Mozambique for the information of exporters, nurserymen, etc.

Notification No. F.7-12/46-PP (Crops), dated the 17th February 1947 of the Government of India in the Department of Agriculture

IT is hereby notified for general information that the following officers are authorised to inspect and grant health certificates in respect of plants or seeds intended for export to the United

Kingdom and other foreign countries, the Governments of which require a certificate of freedom from disease to accompany consignments of plants.

	Officers
Central Government	(i) The Plant Protection Adviser to the Govern ent of India, Department of Agriculture, New Delhi.
	(ii) The Imperial Entomologist, Indian Agricultural Research Institute, New Delhi.
	(iii) The Imperial Mycologist, Indian Agricultural Research Institute, New Delhi.
	Centrally Administered Areas
Baluchistan	(i) Entomologist.
	(ii) Mycologist.
Ajmer-Merwara	(i) Agricultural Officer.
Coorg	Agricultural Officer.
Andamans and Nicobar Island	Agricultural Officer.
	PROVINCES
Bihar	(i) Entomologist, Department of Agriculture, Bihar.
Bombay	(i) The Plant Pathologist to the Government of Bombay, Poona.
	(ii) The Agricultural Entomologist to the Government of Bombay, Poona.
Assam	(i) The Director of Agriculture, Assam.
	(ii) The Director, Tea Experiment Station, Tocklai.
Madras	(i) The Entomologist to the Government of Madras, Coimbatore.
	(ii) The Mycologist to the Government of Madras, Coimbatore.
Bengal	(i) The Entomologist to the Government of Bengal.
	(ii) The Mycologist to the Government of Bengal.
United Provinces	(i) The Plant Pathologist to the Government of the United Provinces, Cawnpore.
	(ii) The Entomologist to the Government of the United Province, Cawnpore.
The North-West Frontier Province	(i) The Director of Agriculture.
Central Provinces and Berar	(i) The Mycologist to the Government of Central Provinces and Berar.
	(ii) The Entomologist to the Government of Central Provinces and Berar.
Sind	(i) Mycologist, Agriculture College, Sakrand.
	(ii) Entomologist, Agriculture College, Sakrand.
Punjab	(i) Mycologist, Punjab Agricultural College, Lyallpur.
	(ii) Entomologist, Punjab Agricultural College, Lyallpur.
Orissa	(i) The Director of Agriculture, Orissa.
	INDIAN STATES
Travancore	(i) Director of Agriculture.
Hyderabad	(i) Entomologist.
	(ii) Plant Pathologist.
Cochin	Director of Agriculture.
Bikaner	Director of Agriculture and Forests.
Mysore	Director of Agriculture.
Bhopal	Director of Agriculture.
Baroda	Commissioner of Agriculture.
Patiala	Director of Agriculture.
Kashmere	Director of Agriculture.

The information regarding the arrangements made and the fee charged for the inspection and certification of plants or seeds intended for export to foreign countries should be obtained by the exporters from the Provincial or State Government concerned direct.

MGIPC—M—III-1-10—16-7-48—600.

Instructions to Authors

Articles intended for the *Indian Journal of Veterinary Science and Animal Husbandry* should be accompanied by short popular abstracts of about 300 words each.

In the case of botanical and zoological names the International Rules of Botanical Nomenclature and the International Rules of Zoological Nomenclature should be followed.

References to literature, arranged alphabetically according to author's names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets; when the author's name occurs in the text, the year of publication only need be given in brackets. If reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and in the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'.

Sources of information should be specifically acknowledged.

As the format of the journals has been standardized, the size adopted being crown quarto (about $7\frac{1}{8}$ in. $\times$ $9\frac{5}{8}$ in. cut), no text-figure, when printed, should exceed $4\frac{1}{2}$ in. $\times$ 5 in. Figures for plates should be so planned as to fill a crown quarto plate, the maximum space availl able for figures being $5\frac{3}{4}$ in. $\times$ 8 in. exclusive of that for letterpress printing.

Copies of detailed instructions can be had from the Secretary, Indian Council of Agricultural Research, New Delhi.